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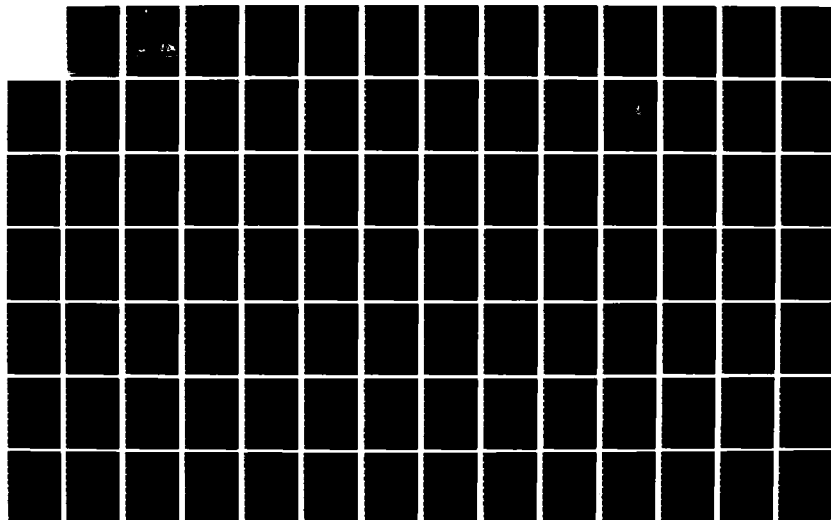
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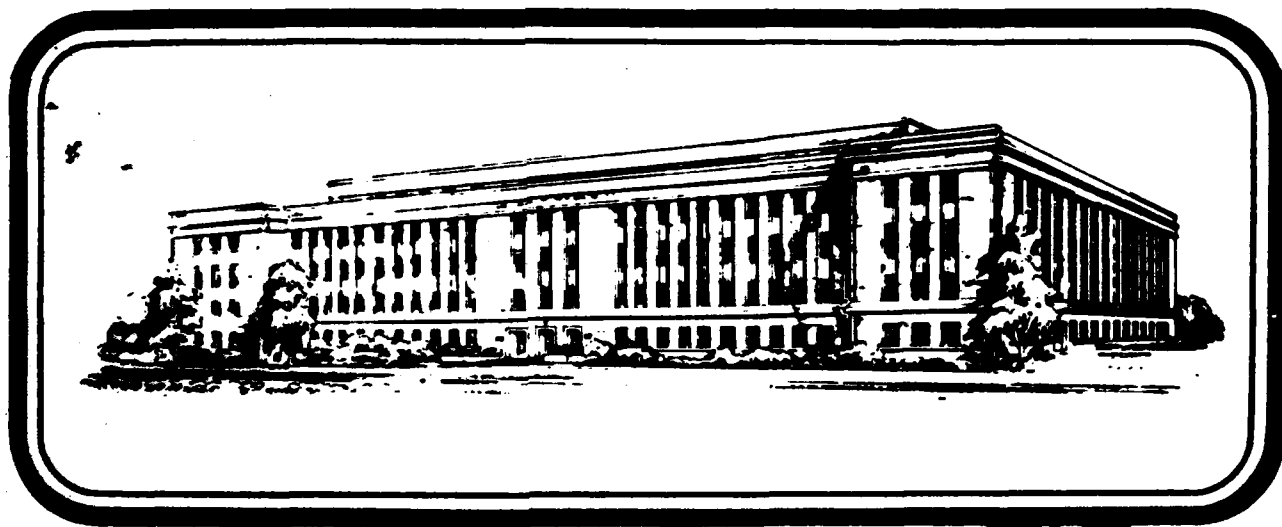
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**MOBILIZATION AND DEFENSE MANAGEMENT
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**CRITICAL NON-FUEL MINERALS IN MOBILIZATION
WITH CASE STUDIES ON COBALT AND TITANIUM**



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THE INDUSTRIAL COLLEGE OF THE ARMED FORCES
NATIONAL DEFENSE UNIVERSITY

MOBILIZATION STUDIES PROGRAM REPORT
CRITICAL NON-FUEL MINERALS IN MOBILIZATION
WITH CASE STUDIES ON COBALT AND TITANIUM

by

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A RESEARCH REPORT SUBMITTED TO THE FACULTY
IN FULFILLMENT OF
THE RESEARCH REQUIREMENT

RESEARCH SUPERVISOR: MR. ESTON T. WHITE

THE INDUSTRIAL COLLEGE OF THE ARMED FORCES

APRIL 1983



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ABSTRACT OF STUDENT RESEARCH REPORT INDUSTRIAL COLLEGE OF THE ARMED FORCES

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Critical Non-Fuel Minerals in
Mobilization with Case Studies
on Cobalt and Titanium

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ABSTRACT

Problem Statement: This paper investigates the U.S. posture with regards to strategic and critical non-fuel minerals. The areas investigated included national policy/legislation, requirements determination, vulnerability, production, substitutes, and foreign and domestic resources. Case studies on Cobalt and Titanium are included as representative examples of specific, critical and strategic materials that are essential to U.S. national security.

Conclusions:

1. The U.S. is at risk for supplies of strategic and critical minerals.
2. Foreign sources of economic raw materials, limited land availability in U.S., restrictive environmental regulations and political interests contributed to the decline of the U.S. industrial base.
3. Substitute materials exist but currently are not economical.
4. The administration has set forth a comprehensive national minerals and materials policy.
5. The national stockpile is a viable hedge against supply shortages during an emergency.

Recommendations:

1. Congress must settle its jurisdictional disputes and for material and mineral policy as it directed for the Administration.
2. Resources must be made available for research and development for economical creation of substitute materials and their processing.
3. Fill the stockpile goals in a timely manner.
4. Enact the pending legislation to facilitate the rebuilding of the industrial base.

THIS ABSTRACT IS UNCLASSIFIED

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EXECUTIVE SUMMARY

This study analyzes the current U.S. posture with respect to strategic and critical minerals. The energy crisis of the 1970's focused attention on non-fuel minerals which could have the same disastrous economic consequences as oil. Non-fuel mineral resources supplied by foreigners became the subject of wide debate as to the effects of a supply curtailment during an emergency.

The national stockpile was created to hedge against catastrophic conditions if supplies were diminished during such an emergency. However, the national stockpile is short of its goals by a major amount in certain minerals. This shortage coupled with the recognized deterioration in the defense industrial base led Congress to pass the National Materials and Minerals Policy, Research and Development Act of 1980. It requires the Administration to establish a coherent national materials and minerals policy and a coordinated program for assuring the availability of materials critical for our nation's well being defense and industrial production. The administration responded with a policy statement and a plan in April 1982. It emphasized activity in the following areas:

1. Federal land availability.
2. Material research and development.
3. Minerals and materials data collection.
4. Strategic and critical materials stockpile policy.
5. Regulatory reform.
6. Coordination of national materials policy through the cabinet council on Natural Resources and Environment.

The body of the paper describes the general nature of the strategic and critical minerals issues and illustrates those issues with case studies on two specific minerals: Cobalt and Titanium. Some conclusions are summarized below:

The United States is at risk with respect to supplies of critical and strategic materials which could impact defense capabilities during emergency situation. This position occurs not only because of our dependence upon foreign sources of supply but as a result of our declining industrial base. This decline was caused by limited land availability, restrictive environmental regulation and to some extent political interests.

Substitute materials are a viable answer to the resource vulnerability problem but the economics of the situation currently does not foster their use. Much needs to be done in research and development on the economic creation of substitutes and their manufacturing process.

The Administration has set forth a coherent policy now we need a coherent approach by Congress to enact the legislation and provide the resources to implement that policy.

Another call for the application of resources is the fulfillment of the national stockpile goals. The legislation exists the resources need only be applied to provide this valuable hedge against supply disruptions.

Pending legislation to update the Defense Product Act of 1950 which focuses on a rejuvenation of the defense industrial base is needed to provide industry the incentives to invest and sustain the industrial capacity necessary for our nation's defense.

CHAPTER I

INTRODUCTION AND BACKGROUND

I.1 A Prologue of U.S. Dependency on Foreign Minerals.

The energy crisis of the 1970's reminded the citizens of the United States that the resources of the earth are finite. In fact, in October of 1973, the Organization of Arab Petroleum Exporting Countries (OPEC) sent shock waves through the world when it announced that it had decided to decrease the production of crude oil and to place an oil embargo on the U.S. and Holland. This historic decision represented a major turning point in Middle East politics, in the relationships between the Arab states and the rest of the world; and, in a wider sense, between raw material producing and consuming nations. There had been some signs before October 1973 that the industrialized nations' visions of an ever expanding use of oil might not be fulfilled. In fact, in the early 1970's, several Arab states had spoken of the need to conserve their resources and to obtain the highest possible revenues for their nonreplenishable resources. Nevertheless, in 1972 few persons in academia, government, or even in the oil industry, were prepared for the development of an oil shortage in the U.S.; or, the subsequent decision by OPEC to use oil as a political weapon to further Arab aims in world politics. The impact of these developments was immediate and far reaching. Oil had become a vital part of every developed country's economy. The U.S., Western Europe, and Japan were suddenly confronted with the prospect of recession or depression, of millions unemployed, and, at best, a tremendous

increase in the costs of their products. The developing nations also were deeply affected, for their aspirations of rapid economic development were suddenly crushed as the price that they had to pay for oil increased sharply, thus draining precious, scarce resources from investment projects. The supply of oil, because of its international dimensions, was clearly an issue that deeply affected the political and economic interrelationships of states, their foreign policies and even the structure of the international system. The Arab use of oil as a weapon to achieve political objectives was branded by many observers and statesmen as blackmail. For those on the receiving end, the Arab action was indeed an attempt to compel a particular action by threats. Oil cartel supporters claimed that the Arabs were simply doing what statesmen had been doing for centuries: employing national resources to secure political aims.¹

The dangers of a high dependence on foreign sources for any item essential to our nation's survival is best illustrated by the OPEC oil embargo. While oil is the best known and most important single commodity subject to possible cartel-type actions, it is important to remember that it is probably not the only one.

No sooner had we somewhat recovered from the energy dilemma, when there were media reports of another type of crisis. Several prominent leaders and government officials were claiming that our industrial base was declining and that we probably could not meet the projected requirements of a war time mobilization effort. This situation became widely known during the hearings of the Defense Industrial Base Panel of the Committee on Armed Services, House of Representatives, in December of 1980. The major findings of the hearings

are detailed in a report entitled, The Ailing Defense Industrial Base: Unready for Crisis. The report stated: "The general conditions of the defense industrial base has deteriorated and is in danger of further deterioration in the coming years; a shortage of critical materials, combined with a resulting dependence on uncertain foreign sources for these materials, is endangering the very foundation of our defense capabilities. These shortages are a monumental challenge to the Congress, the Department of Defense, the defense industry and the civilian economy."²

The energy crisis and the ailing defense industrial base issues both highlighted the fact that the security of industrialized democratic societies depends in large measure not only upon military strength in being but also upon having viable economies. Such economies facilitate development of sophisticated military material and provide a mobilization base with substantial elements capable of rapid conversion to defense and defense-supporting production. Viewed in this context, adequate supplies of virtually every material are a strategic necessity. A brief look at human history reinforces the presumption that we have always been dependent on critical materials.

I.2 Critical Materials - A Historical Perspective.

Food and water, the basic subsistence of man, has always been a strategic importance. The Book of Genesis explains how the stockpile of grain that was stored during the seven years of plenty permitted Egypt to survive the seven years of famine that followed. Wood and stone were strategic materials to ancient man. Copper was a strategic material in ancient Egypt,

followed by bronze in both the Mediterranean world and the Far East.³ The story of ancient civilizations' dependence on critical materials goes on and on.

The United States was concerned early on with the potential availability of strategic materials outside of its own borders. Commodore Perry's Far East Naval Expedition of 1852-1864, had specific orders to look for and to sample likely coal deposits in the Far East in anticipation of the future needs of a steam propelled navy.⁴ However, more than any other industrialized nation of the late nineteenth and early twentieth centuries, the U.S. could meet the most urgent of its mineral needs from within its own borders. But, the capacity of the United States to produce and consume have made it a have-not nation in many of the most important industrial raw materials.

I.3 The U.S. Situation.

The U.S. situation with regard to critical materials is important to understand in this context. However, it is first necessary to examine some definitions in dealing with the problems of mineral dependency. The term 'strategic and critical materials' mean that they are needed to supply the military, industrial, and essential civilian needs of the United States during a national emergency and are not found or produced in the United States in sufficient quantities to meet such need.⁵

The current non-fuel mineral posture indicates that domestically produced non-fuel materials of mineral origin are valued at over \$225 billion annually. Domestic sources account for the major part of our total mineral

materials supplies; but, imports supply significant quantities of a broad spectrum of mineral materials (Figure 1). The result is a non-fuel mineral trade imbalance of approximately \$2 billion. Further, an assessment of strategic vulnerability must include an examination of other countries besides the U.S. Nations with which we are closely allied are even more dependent on imports for important non-fuel minerals than is the U.S. What is significant as well is the communist block is largely self sufficient. This self sufficiency is a result of a long pursued policy of autarky on the part of the U.S.S.R. The development of its mineral resources, within a giant land mass of 8-1/2 million square miles, has been a prime objective of the U.S.S.R. ever since the Revolution of 1917.⁶

An assessment of our position with respect to any particular material must not only include import dependence, but many other factors. Materials on hand in the strategic stockpile, other government stocks, and industry stocks are also significant. For example, our present posture in several important materials such as tin, tungsten, manganese and chromium would be quite different were it not for the strategic stockpile. The strategic stockpile, however, can only be called upon for defense purposes.

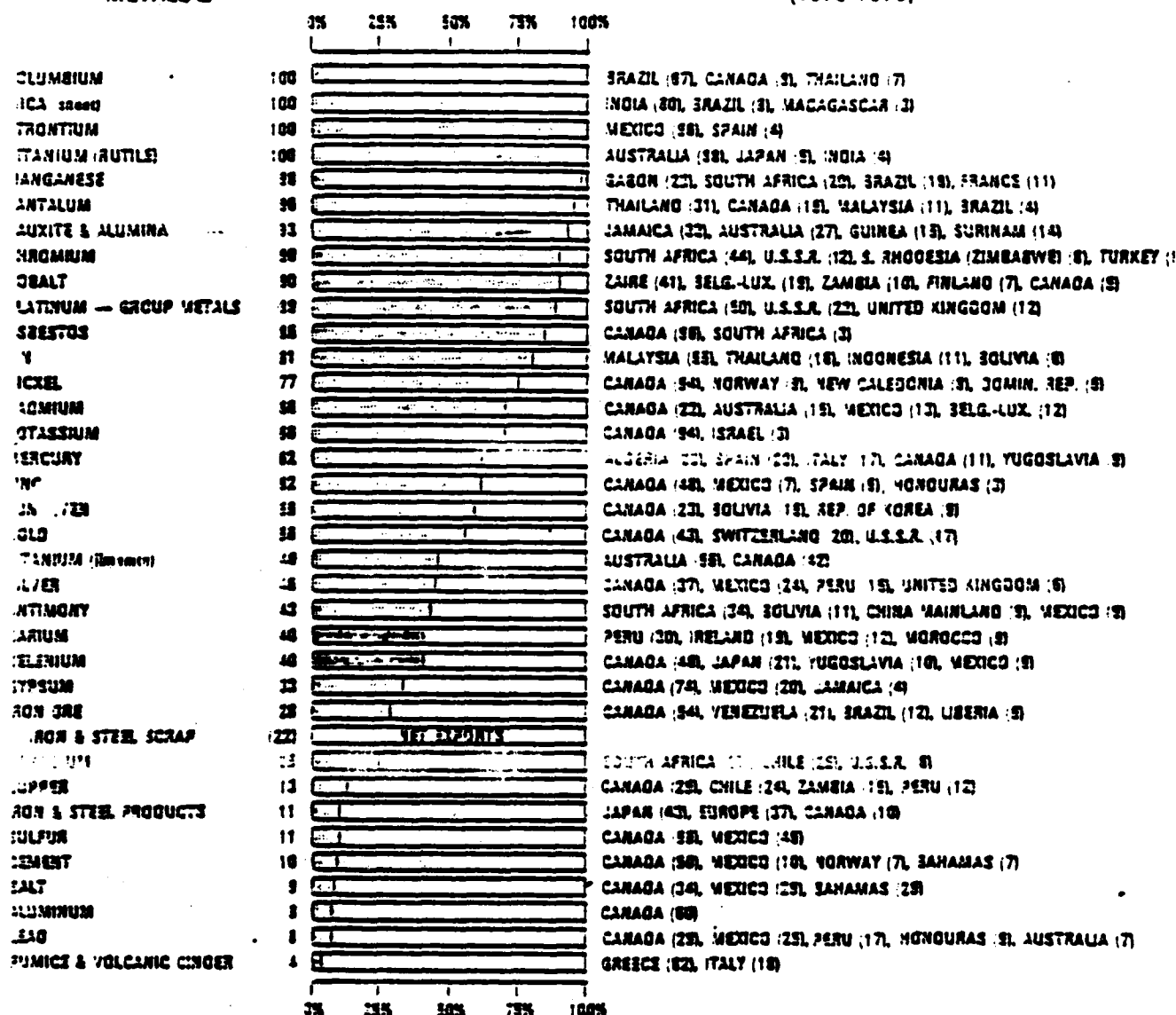
Possibilities of substitutes and alternates must also be considered, as must the possible use of low-grade noncommercial domestic mineral deposits. Deposits considered submarginal today could become sources of supply at some future time. Bureau of Mines research includes recovering chromium, nickel, and cobalt from laterite deposits and from flue dusts, plating wastes and other residues. Another illustration of possible changes

U.S. NET IMPORT RELIANCE OF SELECTED MINERALS AND METALS AS A PERCENT OF CONSUMPTION IN 1979

MINERALS AND METALS^{1/}

NET IMPORT RELIANCE^{2/} AS A PERCENT OF APPARENT CONSUMPTION^{3/}

MAJOR FOREIGN SOURCES^{2/} (1975-1978)



^{1/}NET IMPORT RELIANCE = IMPORTS-EXPORTS
ADJUSTMENTS FOR GOV. AND INDUSTRY
USE / ANGES.

^{2/}APPARENT CONSUMPTION = U.S. PRIMARY
SECONDARY PRODUCTION + NET IMPORT RELIANCE.

APRIL 1980

^{3/}SUBSTANTIAL QUANTITIES ARE IMPORTED FOR RECYCLING,
GRAPHITE, INDIUM AND OTHER DATA WITHIN TO
AVOID DISCLOSING COMPANY PROPRIETARY DATA.

^{2/}SOURCES SHOWN ARE PRINCIPAL SOURCES OF THE
U.S. AND ARE NOT NECESSARILY THE ONLY SOURCES
OF THE MATERIAL.

BUREAU OF MINES, U.S. DEPARTMENT OF THE INTERIOR
IMPORT-EXPORT DATA FROM BUREAU OF THE COMMERCE

exists in the automotive industry. One manufacturer predicted that by 1985 net weights could be reduced by 15-20 percent from 1978 weights. Aluminum, magnesium, plastics and fiberglass are being given increasing attention as substitutes for the traditional steel in an automobile.

I.4 Emergency Management.

Management of our mineral resources is the responsibility of several executive departments. The Department of Interior, pursuant to Executive Orders under the Defense Production Act and the Stockpiling Act, is responsible for emergency readiness plans and programs for non-fuel minerals. The Interior Department is responsible for mines, concentrating plants, refineries, ores, concentrates and other materials treated in such facilities. The Department of Commerce is responsible for facilities and materials that are further along in the chain of processing and utilization; and, it maintains the Defense Materials System to channel materials to defense and defense-related production. Steel, copper, aluminum, and nickel have been designated as controlled materials and are the basis of the Defense Materials System. The Department of Interior has chartered the Emergency Minerals Administration to carry out actual operations in the event of a major emergency. In emergencies, the Department of Interior operates under the direction of the Federal Emergency Management Agency (FEMA). FEMA, an independent agency, was created in 1979 to consolidate the emergency planning, civil defense, and disaster relief functions of the government.

The Bureau of Mines monitors domestic production, imports, exports, stocks, and consumption of all major non-fuel minerals. As a result of this

continual endeavor, the Bureau of Mines has the framework needed to discharge priorities, allocation, and supply expansion responsibilities under the appropriate legislation. In the event of a supply disruption, the first action to be taken would be to monitor exports, followed, if necessary, by export controls. The Secretary of Commerce is charged with monitoring exports and contracts for export of any nonagricultural good and at some point in a serious shortage situation, recourse to the strategic stockpile might be required. Export controls, priorities and allocation, and stockpile releases are only temporary measures with limited effectiveness. Any long standing supply disruption would call for supply expansion programs under Title III of the Defense Production Act. These would cover not only domestic deposits but also deposits in reliable foreign sources. The Bureau of Mines would recommend needed mineral supply expansion programs to FEMA, which would then direct the General Services Administration (GSA) to make the necessary contractual arrangements.⁷

I.5 The Outlook.

The energy crisis of the 1970's and the publicity given the decline of the U.S. defense industrial base has underlined the need to be concerned about critical non-fuel minerals. United States citizens were struck with the fact that we were dangerously vulnerable to the OPEC-type mineral cartels. The

dangers of a high dependence on foreign sources for any item essential to our nations survival is probably best illustrated by the cartel which caused: price escalation, shortages, inflation, dollar devaluation, trade deficits, and economic stagnation (Figure 2). There is reason to believe one, or a combination of similar pressures could occur with materials such as chromium, cobalt, titanium, nickel, and others.

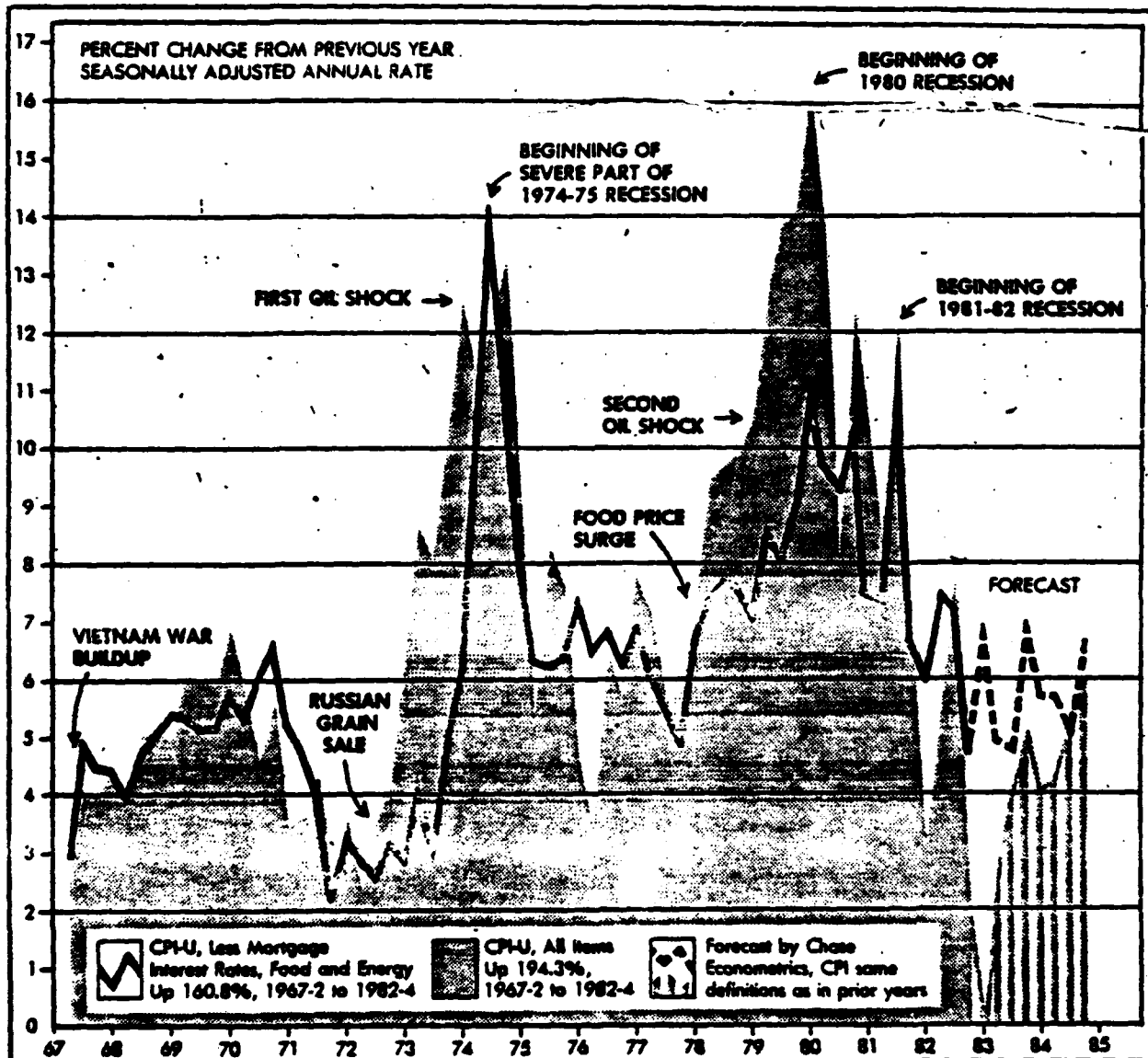
The problems of mineral dependency are foreign, domestic, economic, sociological and political. The questions regarding domestic and foreign resources, foreign dependency, stockpiling, mobilization supplies, production, substitutes and legislation are all interrelated. This report will attempt to provide information, analyze the situation and then synthesize the issues regarding strategic and critical materials. Lastly, conclusions and recommendations are offered to improve the materials impact on national security. Further, two case studies, one on cobalt and the other on titanium are provided as an examination of two representative examples of critical and strategic materials. Cobalt and titanium were selected after consultation with experts from FEMA, Department of Interior, and Department of Defense primarily because of their unique physical properties with regard to their extensive uses in defense-related industries.

I.6 Problem Statement.

This paper investigates the U.S. posture with regards to strategic and critical non-fuel minerals. The areas investigated include national policy/legislation, requirements determination, vulnerability, production, substitutes, and foreign and domestic resources. Case studies on Cobalt and Titanium are included as representative examples of specific, critical and strategic materials that are essential to U.S. national security.

FIGURE 2

A CLOSER LOOK AT THE CONSUMER PRICE INDEX



SOURCE: BUREAU OF LABOR STATISTICS

By Kathy Jungmann for The Washington Post

FOOTNOTES

CHAPTER I (Pages 1-10)

¹Joseph S. Szyliowicz and Bard E. O'Neill, The Energy Crisis and U.S. Foreign Policy (New York: Praeger Publishers, 1975), pp. 1-72.

²U.S. Congress, House, Committee on Armed Services, Defense Industrial Base Panel. The Acting Defense Industrial Base: Unready For Crisis, Report (Washington: U.S. Government Printing Office, 1980), p. 1.

³Morgan, John D. "Strategic and Critical Materials." Paper delivered to American Institute of Mining, Metallurgical and Petroleum Engineers, Washington, D.C. 1980.

⁴Ibid.

⁵James E. Sinclair and Robert Parker, The Strategic Metals War (New York: Arlington House, 1980), p. 2.

⁶Ibid., p. 66.

⁷Morgan, "Strategic and Critical Materials, pp. 11-13.

⁸Sinclair and Parker, The Strategic Metals War, p. 164.

CHAPTER II

VULNERABILITY

II.1 General.

Until well after World War I, the U.S. produced 90 percent of the materials it consumed although even then, significant raw materials were being imported. Since that time, other than briefly during World War II, there has been a steady decrease in both the import and domestic processing of almost all raw materials, and a proportionate increase in the import of the refined and processed materials. ~~Externally~~, this has resulted from the rising trends of nationalism within the third world where the expropriation of U.S. owned companies abroad, together with increased foreign taxation and constraints on U.S. ownership, has reduced U.S. capability to import many raw materials. In addition, many of the countries owning the raw materials, having abundant supply of inexpensive labor, also desire the value added costs that result from refining and processing these materials themselves. Concurrently, high energy and labor costs in this country, together with the restrictive environmental regulations which have greatly increased the difficulty and cost of domestic mineral exploration and processing, have forced U.S. industry to become more heavily dependent on these foreign sources. The end result has been that not only does the U.S. now depend on foreign sources for many of these strategic raw materials but also for processing the materials as well. The decline in U.S. merchant shipping has resulted in an increased dependence on foreign transportation at a time when the U.S. and allied navies no longer can provide uncontested security to the sea lanes connecting the U.S. to its

overseas suppliers. For instance, none of the principal world suppliers of chromite or titanium (rutile), and less than 10% of the suppliers of cobalt, manganese, and platinum group metals are located within the Western Hemisphere, and these materials could be subject to disruption if the sea lanes were closed. The consumption rates for some of these and several of the other critical minerals, however, are in relatively small quantities and could be transported by air if necessary. For several years, virtually all of the cobalt exports from Zaire were flown out of the country due to the insecure rail transportation network in and within neighboring countries.

A more significant consequence has been the overall decline in the industrial base and loss of the associated skills which has simultaneously occurred within the U.S. One of the methods the U.S. has chosen to deal with this vulnerability is the creation of a national stockpile. Currently, there are 93 elements in 61 groups of materials designated as strategic and critical for purposes of maintaining national stockpile reserves. Of these, there are approximately 20 minerals for which the U.S. depends upon foreign suppliers for greater than 50 percent of its supply.¹ Although the annual dependency percentage will vary somewhat, there are also some of these materials for which the U.S. is virtually 100 percent dependent on foreign sources, some of which are distant and of questioned reliability. Pending any government legislation to improve this situation, it is likely to remain unchanged and in all probability will further deteriorate.

"Much of the world's production and reserves of a number of our critical materials are located in two areas of the world;

Siberia and southern Africa. These two areas contain 99 percent of the world's manganese ore; 97 percent of the world's vanadium; 96 percent of the world's chromium; 87 percent of the world's diamonds; 60 percent of the world's vermiculite; and 50 percent of the world's fluorspar, iron ore, asbestos and uranium. Zaire and Zambia now provide 65 to 75 percent of the world's cobalt. In 1979 the U.S. had to import over \$25 billion worth of non-fuel minerals. This dependence on foreign sources for raw materials vital to our industries has been increasing for many years for several reasons including: technology advancements and legislative and regulatory restrictions imposed on the U.S. mining industry."²

Despite many of the concerns expressed, from an overall economic standpoint, the U.S. in 1980 still operated a positive raw materials trade balance of \$6 billion in exports compared to \$5 billion in imports. There was, however, a trade deficit in processed minerals with \$23 billion exported compared to \$25 billion imported with an overall net deficit in 1980 of \$1 billion.³

II.2 External Factors.

Of further concern is the relatively well off position of the U.S. when compared with its allies who depend much more heavily on imports for many of their strategic raw materials. Western Europe imports 75 percent and Japan 90 percent of all its raw materials.

The Soviet Union on the other hand is for all practical purposes, resource independent and in some cases has deliberately invested in developing

production and processing facilities excessive to its apparent estimated needs. It is also spreading its influence in central and southern Africa and other areas upon which the U.S. depends heavily for materials.

This dependency and possible vulnerability of the U.S. to distant foreign sources of supply has been a major concern since the catastrophic political and economic consequences brought on by the oil embargo in 1973. Defense and Industry experts have expressed grave concerns over the spectre of similar situations occurring within the critical non-fuel minerals. They feel the U.S. has now become dangerously vulnerable to an OPEC type mineral cartel or that in the event of full scale hostilities it would be cut off from its overseas suppliers.

Obviously, the vulnerabilities vary for each non-fuel mineral dependent on a number of factors. There is also a wide range of interpretations as to which minerals constitute strategic materials. Although potential domestic sources for several strategic materials are known, their unearthing would require directed incentives. In addition, peacetime exploitation of these could be hampered by predatory foreign producers who could economically afford to substantially reduce the prices on the open market thus rendering U.S. efforts comparatively more expensive if pursued.

Import dependence also does not necessarily imply vulnerability since there are varying degrees of both dependence and vulnerability. For instance, the U.S. currently receives 25 percent of its non-fuel mineral imports from Canada a friendly country and reliable supplier. In addition, of 12 critical minerals identified as vital to U.S. defense production efforts; seven

minerals, cobalt, columbium, nickel, platinum group metals, tantalum, titanium (ilmenite) and tungsten are produced, some in significant quantities, and exported by Canada. So while the U.S. is in all probability most import dependent on Canada, it is also least vulnerable to a cut off by Canada based on the historical good relations that have existed between our two countries. At the same time, while many of these materials are readily available from Canada and other neighboring countries during peacetime conditions, assuming that Canada would continue to be an ally in the event of worst case scenario, a prolonged conventional war with the Soviet Union, (nuclear warfare not being considered relevant to this problem) Canada might be hard pressed to support U.S. surge requirements while at the same time trying to meet their own increased defense needs. Assuming, of course, that U.S. defense industries remain somewhat capable of conducting a surge in production. Reliance on either Canada or Mexico where land transportation is relatively secure, is obviously less vulnerable than an unstable or unfriendly country located thousands of miles across the ocean.

On the other hand, our greatest vulnerability would be our dependence for mineral resources imported from the Communist countries; however, other than chromium some of which the U.S. obtains from the U.S.S.R., the U.S. imports little in the way of significant quantities of these materials from these countries. Even during the Vietnam war, the U.S. was still importing chromium from the U.S.S.R. This in spite of the fact that the Soviets had imposed a chromium embargo during the Korean war.

Some of the other factors that must be considered when assessing the vulnerability of any given material are:

- Major and alternate suppliers.
- Number of suppliers and their geographic distribution.
- Political and economic reliabilities of suppliers.
- Relationships or associations between common suppliers.
- Geographic proximity of suppliers to the U.S. and other suppliers.
- Transportation network across land, together with access to ports and sea lanes and distances to be travelled.
- Potential for disruption of production or transportation due to cartel, embargo, civil war or uprising, hostile neighbor or other activities.
- Availability of substitutes and in turn reliability of sources or suppliers of these substitutes.
- Quantities of materials required and quantity of this material in the National Stockpile.
- Essentiality for the defense effort.
- Impact of disruption to U.S. mobilization efforts and economy from short to long-term cut off.
- Dependence of the suppliers' economy on U.S. market for the material.
- Availability of domestic deposits and time required to achieve production level.

II.3 Internal Factors.

In addition to the external factors that contribute to U.S. vulnerability, certain U.S. government environmental and human rights policies

are contributing factors to the degree of vulnerability. For instance, several years ago, while chromium demands were high, environmental laws on clear air caused an increase in chromium for pollution control equipment and devices. At the same time, the U.S. government unilaterally placed an embargo on Rhodesia (Zimbabwe) who was then our chief importer of chromium. Other environmental restrictions were also imposed on the obsolescent ferrochromium industries in this country thereby reducing their production capabilities while the export of stainless steel scrap, each ton containing approximately 400 pounds of chrome, was unrestricted.⁴

Investment in non-fuel mineral production has been substantially reduced in the past several years and many legislative actions continue to undermine what was ten years ago a stable and healthy domestic mining industry. Accompanying the move of investment to more profitable industries, has been a migration of the technical talents further eroding the industry by decreasing know-how and further discouraging investment. At the same time, U.S. lands have been withdrawn from exploration and development, and environmental policies have forced the processing of minerals overseas. In part, the blame for some of this can be placed on both the government and on industry. Government places tight environmental controls on the mining and processing industries in order to protect our own environments; industry on the other hand cannot afford the high prices of these controls and thus both evade the responsibilities by exporting the pollution problems to other nations. Thus, a more comprehensive strategic and critical minerals policy must be created to integrate the needs of the nation for defense materials, clean air and political interests.

FOOTNOTES

CHAPTER II (Pages 12-18)

¹Morgan, John D., Past is Prologue: Strategic Materials and the Defense Industrial Base, Defense Management Journal, First Quarter 1982, p. 15-19.

²Report of the Defense Industrial Base Panel of the Committee on Armed Services, House of Representatives Ninety Six Congress, 2nd Session, The Ailing Defense Industrial Base: Unready for Crisis, U.S. Government Printing Office, December 31, 1980.

³Calingaert, Michael, U.S. Strategic Minerals Dependency, Department of State Bulletin, Vol. 81, No. 2049, April 1981, p. 23.

⁴Gray, Allen G., Case for a National Minerals Policy, Metal Progress, February 1980, p. 31.

CHAPTER III

PRODUCTION

Under the Defense Production Act of 1950, as amended, and the Defense Industrial Reserve Act of 1973, the Secretary of Defense is tasked with maintaining the nucleus of government owned plants and equipment to support defense needs in a national emergency. The latter act further stipulates that to the maximum extent possible reliance will be placed on the private sector to support defense needs.

Thus prime reliance is placed on approximately 25,000 to 30,000 prime contractors and over 50,000 other subcontractors, and while DOD production and maintenance facilities are extensive many are old and in poor repair. Since private industry operates on a profit motive together with assurances of continued long term operation, these incentives become the necessary motivators by government seeking to attract contractors. However, since the Vietnam war many contractors have found government contracts unattractive due to their short duration and the many policies and regulations they are forced to comply with.

Among the major findings in the Report of the Defense Industrial Base Panel on the Committee on Armed Services, House of Representatives during the second session of the Ninety-Sixth Congress on "The Ailing Defense Industrial Base: Unready for Crisis" (Committee Print No. 29) were these:

FINDINGS AND RECOMMENDATIONS

Among the major findings of the panel were the shortages of critical materials with a resulting increased dependence on uncertain foreign sources for these materials. It was felt that this dependence was endangering the very foundation of our defense capabilities. It was recognized that these actual and potential shortages represented a monumental challenge to Congress, the Department of Defense, the defense industry overall and the civilian community.

In addition the general condition of the defense industrial base was identified as having seriously deteriorated and was in danger of further deterioration in the future; and that there appeared to be no on going Department of Defense programs of adequate plans to address this problem.

Included in the specific findings related to the shortages of critical materials and the resultant heavy dependence on foreign sources for these materials, was the fact that the U.S. did not have an effective non-fuel minerals policy that promotes U.S. national security interests. Also cited was the lack of knowledge about the total potential mineral resources of this country and the excessive governmental regulations which stifle and cripple the basic mineral industries of the U.S. Many of the identified resources which exist within the 750 million acres of public lands cannot be further explored or developed due to restrictive environmental regulations.

The critical materials existing within the national stockpile are in some cases woefully inadequate to meet the industrial base requirements. In

other cases, those materials on hand were not of sufficient purity or in a form adequate to meet the needs of current technology. Thus necessitating additional processing in order to expedite their usage during a time of emergency.

The basic provisions of the Strategic and Critical Materials Stockpiling Act (50 U.S.C. 98) and Title III of the Defense Production Act of 1950 (50 U.S.C. App 2061) were not being adequately implemented.

Included in expert testimony during the Defense Industrial Base Panel proceedings were the following comments on the general state of the industrial base as it existed at the end of 1980.

- There was a significant increase in production lead times after 1976, for example:
 - From 1976 to 1980, the typical delivery span of aluminum forgings increased from 20 to 120 weeks.
 - From 1977 to 1980, the delivery span for aircraft landing gears grew from 52 to 120 weeks.
 - From 1978 to 1980 the delivery span for integrated circuits more than doubled, from 25 to 62 weeks.
 - From 1978 to 1980 normal lead times for military jet engines increased from 19 to 41 months

Many of these lead time bottlenecks resulted from the closure of forging and casting facilities and the lack of construction of new facilities. During the 1970s literally hundreds of foundries closed as a result of environmental, health and safety laws and regulations imposed by the Federal Government.

- In the area of critical manpower shortages, it was predicted that the country would be short 250,000 machinists by 1985. Unlike in World War II, when under full mobilization thousands of farmers, housewives, construction laborers, clerks and others were rapidly trained within weeks to build thousands of aircraft engines, today's engine tolerances are too tight and the equipment too sophisticated and would require from one to three years of specialized training.
- The lack of investment by the defense sector of U.S. Industry has resulted in a situation where 60 percent of metal working equipment used in defense contracts is over 20 years old.
- Government policies have proven to be counter productive and discouraging to the discovery and development of mineral deposits. There are 80 different laws administered by 20 different federal agencies which directly or indirectly affect the domestic non-fuel mineral industry.

In addition to the self imposed policies which have helped to erode the industrial base is the factor of foreign competition which in many cases is subsidized by the competing governments. We import many raw materials and also send our raw material overseas because it is cheaper than what it would cost us to mine or process them domestically. In order to remain in business many U.S. firms are setting up plants overseas where labor costs, environmental standards, taxes and energy and transportation costs are more favorable. We find, however, that we are becoming more and more dependent on

foreign suppliers. This benefits us during time of relative peace, but it could prove catastrophic during periods of hostilities in which we are cut off from our suppliers and no longer have the domestic capabilities to support ourselves. This situation has occurred directly in the aluminum, copper, zinc and ferrous alloy industries, where American mining industries have shifted ^{iv} these industrial processing operations to locations outside the continental United States. It has also occurred indirectly due to foreign competition in end products. The foreign competition in the automobile industry has had only impacted on the domestic automobile producers themselves, but has also had a widespread impact on the steel industry and many other associated industries all the way back to the suppliers of basic raw materials.

FOOTNOTES

CHAPTER III (Pages 20-24)

¹Report of the Defense Industrial Base Panel on the Committee on Armed Services, House of Representatives, Second Session, Ninety-Sixth, Congress. The Ailing Defense Industrial Base: Unready for Crisis (Committee Print No. 29).

Other Source:

Gansler, Jacques S., The Defense Industry Underlying Economic Factors, Production Factors 1980, pp. 63-69.

CHAPTER IV

SUBSTITUTION

IV.1 General.

Many materials exist which can be used as substitutes for strategic and critical material. The possibilities of substitution vary considerably from metal to metal, and in some cases the metals to be used as substitutes are as strategic and vulnerable as the metals they are to replace. To a large extent, while substitutes for many items have been available for many years, factors such as relative physical properties with respect to desired performance, comparative prices and current state of technology determine the extent of their usage.

IV.2 Substitutes.

The U.S. Bureau of Mines has documented many acceptable substitutes, however, many of these are either currently more expensive or do not meet the performance standards desired. Other substitutes are of equal cost and performance but would require several years to transition into the alternate and with a relatively stable supply of the existing critical material ensured under peacetime conditions, there is little incentive to make the change.

One of the most critical minerals for American industry, and the defense effort in particular, is chromium for which the U.S. is almost 100 percent dependent on South Africa and to some extent the Soviet Union. As with other strategic minerals, several new low chromium free alloys have

already been developed that could greatly reduce western demand for chromium, but chromium's relative abundance on the market and favorable buildup in the national stockpile, together with current low prices, have not provided sufficient incentives to justify full-scale commercial production of these substitutes.¹

IV.3 Composites.

One of the most attractive and widely known area of substitute possibilities is the family of composites. The Department of Defense has also been working on composite materials for almost 20 years. Composites are man-made materials composed of two or more components which when bonded have properties different from those of the respective components. They usually consist of reinforcing fibers imbedded in a plastic, metal or carbonaceous material.

The Navy has investigated numerous applications for metal matrix composites. Substitution of metal-matrix composites for steel in supersonic tactical missiles can provide weight savings of almost 70 percent. The use of carbon/carbon composites provides substructure thermal protection on advanced reentry systems and the metal-matrix composites higher allowable service temperatures are used with the carbon composite heat shields. The Navy is also investigating the use of metal-matrix composites in high energy lasers in which a 400 percent weight reduction is possible when compared with current molybdenum optics.

These metal-matrix composites also offer substitution potential for critical or long lead-time materials such as chromium, cobalt, titanium, or

beryllium. A graphite fiber reinforced magnesium alloy composite has the stiffness, strength and dimensional stability properties equal or superior to those of beryllium at the same weight. In another example, titanium sheet clad graphite fiber demonstrated structural properties comparable to a solid sheet of titanium one and one half times thicker using only seven percent titanium. This composite can save as much as 93 percent of the titanium conventionally used. A great deal of attention is being given to these composites as substitutes for strategic and critical material since they are all produced domestically.²

Some of the most critical materials are used in high performance jet engines and while substitutes could be used in commercial aircraft engines with an acceptable degradation in performance, they would be unacceptable for use in military aircraft engines where the outcome of air activities depend primarily on aircraft performance.

IV.4 Conservation.

The F-100 turbofan engine which powers two of our most modern airplanes, the F-15 and F-16 requires 14,030 pounds of materials all of which is categorized as strategic and critical, 5366 pounds of titanium, 5204 pounds of nickel, 1656 pounds of chromium, 910 pounds of cobalt, 720 pounds of aluminum, 171 pounds of columbium and three pounds of tantalum.³ With the exception of chromium, the stockpile holdings for these are far below the levels required. Additionally, fabrication of the engine components involves much wasted effort and considerable loss or down grading of the materials. The completed engine only weighs 3020 pounds, thus achieving the shapes and

forms desired in the final product means a weight loss of eighty percent of the materials originally used. Research is underway to find substitutes and alternate materials to develop near net shape forming and to recycle the high alloy scrap. While conservation is desirable, reprocessing the scrap must also be economically competitive with the market prices.⁴

As prices of critical materials increase, substitution and recovery processes will become more practical and in the long run, recycling will become increasingly more important to domestic critical materials production. Substitutes for critical and strategic materials are available, however, they are not currently economical substitutes. Although much development has taken place more is needed in areas of producing substitute materials and the manufacturing processes to make them viable competitors in the market place. The substitute materials must be taken out of the laboratory and put into production.

FOOTNOTES

CHAPTER IV (Pages 26-29)

¹Now the Squeeze on Metals, Business Week, 2 July 1979, pp. 16-51.

²Stockpile Reports to the Congress, October 1981 - March 1982, Federal Emergency Management Agency.

³Morgan, John D., "Strategic and Critical Materials," Paper delivered to American Institute of Mining, Metallurgical and Petroleum Engineers, Washington, D.C., 1980.

⁴"Past is Prologue: Strategic Materials and the Defense Industrial Base," Defense Management Journal, First Quarter 1982, pp. 15-19.

Other Sources:

U.S. Air Force Academy Hildebrandt, Gregory G., Strategic Stockpiling and Substitution, Final Report, January 1978, pp. 1-25.

CHAPTER V

NATIONAL POLICY

V.1 Introduction.

Prior to 1980, the United States lacked a formal, comprehensive, and coherent statement of national policy on strategic and critical non-fuel minerals. This deficiency was corrected on 21 October 1980 with the passage of the National Materials and Minerals Policy, Research and Development Act of 1980 (PL96-479). The 1980 law requires that the program for implementation of this policy be coordinated through the Executive Office of the President. Hence, the President has established the Cabinet Council on Natural Resources and Environment for the purpose of coordinating national materials policy.

The National Materials and Minerals Policy, Research and Development Act of 1980 was preceded by such key pieces of legislation as The Strategic and Critical Materials Stockpiling Act of 1946, The Defense Production Act of 1950, and The Strategic and Critical Materials Stockpiling Revision Act of 1979. These pieces of legislation form the foundation for establishing a comprehensive, coherent program for assuring the availability of necessary supplies of strategic and critical non-fuel minerals. Pertinent provisions of the aforementioned legislation are presented below.

V.2 The Strategic and Critical Materials Stockpiling Act of 1946 (PL 79-520).

The Strategic and Critical Materials Stockpiling Act of 1946 is the

cornerstone of legislation with respect to national policy for strategic and critical materials. Section 98 of the Act declares the following policy:

...to supply the industrial, military and naval needs of the country for common defense, it is the policy of Congress and the purpose and intent of...this title to provide for the acquisition and retention of stocks of these materials and to encourage the conservation and development of sources of these materials within the United States, and thereby decrease and prevent wherever possible and dangerous and costly dependence of the United States upon foreign nations for supplies of these materials in times of national emergency.¹

Section 98d of the Act provides that the President can authorize the use of materials from the stockpile when "...such release is required for the purposes of the common defense or in time of war, or during a national emergency with respect to common defense..."²

V.3 The Defense Production Act of 1950 (PL 81-774).

The Defense Production Act of 1950 supplements the Stockpiling Act of 1946. The Act gives the President the authority to divert certain materials and facilities from civilian use to military and related purposes, when such diversion is required for reasons of national security. The Act also gives the President the authority to expand certain productive facilities beyond the levels needed to meet the civilian demand, when such expansion is required for reasons of national security.³

Title I of the Defense Production Act of 1950 provides specific authority for priority in contracts and orders and priority in the allocation of materials and facilities. Title I reads as follows:

The President is authorized (1) to require that performance under contracts or orders (other than contracts of employment) which he deems necessary or appropriate to promote the national defense shall take priority over performance under any other contract or order, and, for the purpose of assuring such priority, to require acceptance and performance of such contracts or orders in preference to other contracts or orders by any person he finds to be capable of their performance, and (2) to allocate materials and facilities in such manner, upon such conditions, and to such extent as he shall deem necessary or appropriate to promote the national defense...⁴

It authorizes the use of priorities to insure that authorized national defense programs are executed and that defense agencies, contractors, sub-contractors, and their suppliers are provided priority treatment for the purchase of products and materials, when necessary. The priority provided by the Defense Priority System insures a timely flow of materials and components to any program that is vital to our national security. This is not a Department of Defense priority system. Rather, it is a National Priority System. In fact, in the recent past, Congress gave priorities to "the Alaskan petroleum and natural gas pipeline projects, to materials for large oil tankers, and to other energy-related projects."⁵

The Defense Priority System establishes two types of ratings for defense orders, DO and DX. The DO rating is normally applied to all defense orders. Orders with DO ratings are given preferential treatment over unrated orders. The DX rating takes priority over DO. Its use is limited to urgent national programs and Presidential approval is required.⁶

Title III of the Defense Production Act of 1950 provides broad authority for expanding supplies of materials, and it makes specific provisions for exploration, development, and mining of strategic and critical minerals and metals. It also makes specific provisions for the development of substitutes for strategic and critical materials.⁷ Title III makes it possible to achieve the aforementioned expansion of supplies of materials and productive capacity by giving the President the authority to authorize:

(1) Loan guarantees to public or private financing institutions that provide financing to contractors for the purpose of enabling that contractor "to expedite production and deliveries or services under Government contracts for the procurement of materials or the performance of services for the national defense."⁸

(2) Direct government loans to private business enterprises "for the expansion of capacity, the development of technological processes, or the production of essential materials, including the exploration, development, and mining of strategic and critical metals and minerals."⁹

(3) Purchases or purchase commitments of "metals, minerals, and other materials, for Government use or resale and for the encouragement of exploration, development, and mining of critical and strategic minerals and metals."¹⁰

(4) Subsidy payments on domestically produced critical minerals and raw materials from high-cost sources "to insure that supplies from such high-cost sources are continued, or that maximum production...is maintained."¹¹

(5) The installation of additional equipment, facilities, processes or improvements to plants, factories, and other industrial facilities owned by either the Government or private enterprise when such installation will aid the national defense.¹²

The authorities granted to the President under the Defense Production Act of 1950 appear to be sufficient to enable us to correct many of the problems related to domestic sources of non-fuel minerals. However, "in 1975 Congress severely limited the broad language of the Act to provide that all authority extended under Title III shall be effective for any fiscal year only to the extent, or in such amounts as are provided in advance in Appropriation Acts. In other words, unless Congress appropriates the funds, Title III may not be used."¹³

In addition, the 1981 Summer Study Panel of the Defense Science Board evaluated the Defense Priority System. The Defense Science Board Report stated:

The system is not working very well. A 1979 survey conducted by students of the Industrial College of the Armed Forces found that only about half of DO rated orders were given priority... The vendor survey conducted by Texas Instruments determined that compliance was good at the first tier, only 50 percent at the

second, and 25 percent at the third tier... The reasons for the difficulties are varied, but one of the principal conclusions is that the system isn't well understood by either government or contractor personnel. This causes excessive paperwork and undermines the purpose of the system, and causes those that the system are intended to assist to question the usefulness of the process...¹⁴

V.4 The Strategic and Critical Materials Stockpiling Revision Act of 1979
(PL 96-41).

The strategic and Critical Materials Stockpiling Revision Act of 1979 reaffirmed the need for stockpiling, conservation, and development of domestic sources of non-fuel minerals. Section 2, paragraph (a) of the Act states:

The Congress finds that the natural resource of the United States in certain strategic and critical materials are deficient or insufficiently developed to supply the military, industrial, and essential civilian needs of the United States for national defense.¹⁵

Paragraph (b) of section 2 continues as follows:

It is the purpose of this Act to provide for the acquisition and retention of stocks of certain strategic and critical materials and to encourage the conservation and development of sources of such materials within the United States and thereby to decrease and to preclude, when possible, a dangerous and costly dependence by the United States upon foreign sources for supplies of such materials in times of national emergency.¹⁶

The Stockpiling Revision Act of 1979 specifies that "the purpose of the stockpile is to serve the interest of national defense only and is not to be used for economic or budgetary purposes."¹⁷ This provision is undoubtedly designed to preclude such past practices as President Johnson's sale of materials from the strategic stockpile at the height of the Vietnam War for purposes of market control and President Nixon's thwarted attempt to use stockpile sales for purposes of price control and as a means to raise revenues to balance the budget.¹⁸ Indeed, the Congress clearly intends that revenues generated from the sale of commodities from the stockpile will be used to replenish the stockpile. Accordingly, the Stockpiling Act of 1979 establishes, within the Treasury of the United States, a National Defense Stockpile Transaction Fund which will serve as the repository for all moneys received from the sale of materials in the stockpile. These moneys are to remain in the Fund until they are appropriated by the Congress, and such appropriation will be only for the acquisition of strategic and critical materials for the National Defense Stockpile.¹⁹

The Stockpile Revision Act of 1979 also stipulates that "the quantities of the materials stockpiled should be sufficient to sustain the United States for a period of not less than three years in the event of a national emergency." Hence, current National Security Council policy guidance for stockpiling of strategic and critical materials is based on planning for the first three years of a war of indefinite duration.

The Stockpiling Act of 1979 provides a clear definition of strategic and critical materials as follows:

"(1) The term 'strategic and critical materials' means material that

- (A) would be needed to supply the military, industrial, and essential civilian needs of the United States during a national emergency, and
- (B) are not found or produced in the United States in sufficient quantities to meet such need.

(2) The term 'national emergency' means a general declaration of emergency with respect to the national defense made by the President or by the Congress."²¹

V.5 The National Materials and Minerals Policy, Research and Development Act of 1980 (PL 96-479).

The National Materials and Minerals Policy, Research and Development Act of 1980 was enacted by the Congress in response to compelling criticism that the United States lacked a coherent national materials and minerals policy and a coordinated program for assuring the availability of materials critical for national economic well-being, national defense, and industrial production. The 1980 Act contains the following national policy statement on materials and minerals:

The Congress declares that it is the continuing policy of the United States to promote an adequate and stable supply of materials necessary to maintain national security, economic

well-being and industrial production with appropriate attention to a long-term balance between resource production, energy use, a healthy environment, natural resource conservation, and social needs.²²

The Act required the President to report to the Congress his program plan to implement and carry out the national materials and minerals policy.

The act stipulates the following:

The plan shall include program and budget proposals and organizational structures providing for the following minimum elements:

- (A) policy analysis and decision determination within the Executive Office of the President;
- (B) continuing long range analysis of materials use to meet national security, economic, industrial and social needs; the adequacy and stability of supplies; and the industrial and economic implications of supply shortages or disruptions;
- (C) continuing private sector consultation in Federal materials programs; and
- (D) interagency coordination at the level of the President's Cabinet.²³

Passage of the 1980 Act led to the formation of the Cabinet Council on Natural Resources and Environment which is chaired by the Department of the Interior. National materials policy will be coordinated through this Council.

On 5 April 1982, President Reagan transmitted to the Congress his program plan on the activities to be undertaken by his Administration to decrease America's minerals vulnerability. The President made the following statement of policy:

It is the policy of this Administration to decrease America's minerals vulnerability by taking positive actions that will promote our national security, help insure a healthy and vigorous economy, create American jobs, and protect America's natural resources and environment.²⁴

The President's plan emphasizes the following areas as focal points for the Administration's activities regarding the reduction of materials vulnerability:

- A. Federal Lands Availability.
- B. Materials Research and Development.
- C. Minerals and Materials Data Collection.
- D. Strategic and Critical Materials Stockpile Policy.
- E. Regulatory Reform.
- F. Coordination of National Materials Policy Through the Cabinet Council on Natural Resources and Environment.²⁵

National policy and associated legislation provide a very adequate basis for the U.S. to undertake a comprehensive non-fuels minerals program aimed at achieving the 3-year stockpile goal for each of the critical materials contained in the national stockpile. However, successive administrations and the Congress have lacked the will to procure sufficient

quantities of strategic and critical materials to sustain the U.S. for a 3-year period in the event of a national emergency. Therefore, annually, the Administration should request, as a matter of priority, and the Congress should be pressured to appropriate funds to make purchases for the national stockpile. Additionally, the Administration should, on an annual and a priority basis, take advantage of the provisions of Title III of the Defense Production Act of 1950 to expand this nation's productive capacity for strategic and critical minerals and ,hence, lessen our dependency on foreign sources.

FOOTNOTES

CHAPTER V (Pages 31-41)

¹U.S. Laws, Statutes, etc., "The Strategic and Critical Stockpiling Act of 1946," United States Code Annotated, Title 50--War and National Defense, (St. Paul, Minn.: West Publishing Co., 1951), sec. 98, pp. 56-57.

²Ibid., sec. 98d, p. 61.

³U.S. Laws, Statutes, etc., "The Defense Production Act of 1950," United States Code Annotated, Title 50--War and National Defense, Appendix Sections 1501 to End, Emergency and Post-War Legislation, (St. Paul, Minn.: West Publishing Co., 1951), sec. 2062, p. 312.

⁴Ibid., sec. 2071, p. 312-313.

⁵Jacques S. Gansler, The Defense Industry, (Cambridge: The MIT Press, 1982) paperback edition, p. 67.

⁶Office of the Under Secretary of Defense for Research and Engineering, Report of the Defense Science Board 1980 Summer Study Panel on Industrial Responsiveness, (Washington: January 1981), p. 63.

⁷Ibid., U.S. Laws Statutes, etc., sec. 2093, p. 327-328.

⁸Ibid., sec. 2091, p. 326.

⁹Ibid., sec. 2092, p. 327.

¹⁰Ibid., sec. 2093, p. 327-328.

¹¹Ibid., p. 328-329.

¹²Ibid., p. 329.

¹³Department of the Air Force, The Air Force Systems Command Statement on the Defense Industrial Base, Issues by General Alton D. Slay, Commander Air Force Systems Command, (Washington: Department of the Air Force, 13 November 1980), p. VII-2.

¹⁴Ibid., Office of the Under Secretary of Defense, p. 64.

¹⁵ Federal Emergency Management Agency, Stockpile Report to the Congress, October 1981 - March 1982, (Washington: September 9, 1982), p. 23.

¹⁶Ibid.

¹⁷Ibid.

¹⁸Cecilia M. Brown, "The Strategic and Critical Materials Stockpile," Joint Perspectives, Spring 1981, p. 17-18.

¹⁹Federal Emergency Management Agency, Stockpile Report to the Congress, October 1981 - March 1982, p. 26.

²⁰Ibid., p. 23.

²¹Ibid., p. 27

²²U.S. Laws, Statutes, etc., "National Materials and Minerals, Policy, Research and Development Act of 1980," United States Statutes at Large, Public Law 96-479, 96th Congress, 2d sess. (Washington: U.S. Government Printing Office, 1981), v. 94, pt. 2, p. 2305-2306.

²³Ibid., p. 2307.

²⁴The White House, National Materials and Minerals Program Plan and Report to Congress, (Washington: April 5, 1982), p. 1.

²⁵Ibid., pp. 1-19.

CHAPTER VI

NATIONAL STOCKPILE -REQUIREMENTS DETERMINATION

VI.1 General.

In the U.S. today a Stockpile exists to serve the interests of national defense. Ninety-three materials exist in the national stockpile¹ basically because of import vulnerability. This list of materials change as new materials are developed such as titanium, tantalum or columbium and as substitutes or alternatives are developed.

The Annual Materials Plan is a list of stockpile materials proposed for acquisition and disposal developed each year through an interagency committee chaired by the Federal Emergency Management Agency (FEMA). The other agencies on the steering committee include: Departments of Defense, State, Commerce, Interior, Energy, Agriculture, and Treasury, the Central Intelligence Agency, the General Services Administration and the Office of Management and Budget. The planning process begins with the preliminary proposed list of materials for purchase or disposal prepared by FEMA.²

This proposed list is developed by developing annual stockpile goals and comparing them to the current stockpile inventory. These stockpile goals are determined based upon the shortfall between requirements and supplies.

VI.2 Requirements Estimates.

The estimated requirements are determined by using the following procedures:

(a) This phase begins with projections of the Gross National Product (GNP) using the Chan Econometric Model. The GNP forecast is driven by macroeconomic estimates of approximately 50 variables. These variables are consistently estimated within the context of a three year non-nuclear war preceded by one year of warning or mobilization.

(b) The National Security Council planning assumptions provide the major policy adjustments to the variables to develop a comprehensive wartime GNP. These planning assumptions adjust imports, exports, investment and personal consumption.

(c) Estimates for wartime GNP are developed for three tiers, defense, essential civilian, and industrial components of the economy. This is done to take national security priorities into account and explicitly recognizing that a pound of cobalt for a turbine engine is more important than a pound of cobalt for ceramic tile coloration. The three tiers are defined as follows:

(1) Defense - All production necessary to obtain weapons, manpower and support including the production necessary to support suppliers of Department of Defense contractors.

(2) Essential Civilian - Those expenditures necessary to maintain the health, safety, morale and productivity of that segment of the population in support of the war or emergency.

(3) General Civilian - Those expenditures, which often belt-tightening, are necessary to support the population and maintain a viable industrial base.³

(d) The wartime GNP estimates of production levels for individual industries are developed separately for these tiers defined above.

The GNP tiers are separated in approximately 250 categories and using Demand Impact Transformation Tables are converted from GNP data into final demand for outputs of 109 industries. Using Department of Commerce historically developed material consumption ratios, the physical consumption of each of the strategic materials is computed for each specific industry. The GNP X Material Consumption Ratios provide estimates of:

- (1) Each industry for material's consumption
- (2) Each tier and
- (3) Each year of the war.

(e) Final adjustments are made which account for material substitution. Planning factors geared to variable risk modify the rates at which industries substitute one material for another. With this final adjustment, the total requirements for a material in a particular tier in a given year are created.⁴

VI.3 Supply Estimates.

The second major calculation is the available supply.

These supply estimates for each material are based upon the sum of current domestic production, capacity and expected imports. This information is developed by the commodity experts in the Department of Interior (Bureau of Mines) and the Department of Commerce (Bureau of Domestic Commerce). Domestic production and capacity information gathering is rather straightforward.

Foreign sources of supply may vary considerably in wartime versus peacetime. Thus, the quantity is adjusted after examining normal supply

patterns and expanded production possibilities, where mines and other production facilities are assumed to operate at capacity. The United States is assumed to receive a proportionate share of the increased supplies.

Once the import supply estimates are developed they are discounted by the following factors:

- (1) Countries in the zone of action are deleted.
- (2) A political reliability factor is applied to the remaining countries conditioned by the following factors:
 - (a) Political orientation toward the United States
 - (b) Ability to sustain stockpile material exports in wartime
 - (c) Dependability of the labor force in wartime and
 - (d) Vulnerability to sabotage.⁵

The Department of State rates the supplier countries with Central Intelligence Agency inputs. The Federal Emergency Management Agency analyzes the resulting numerical rankings of supplier countries and determines their contribution to supplied quantities. Countries ranked below the 35th percentile are not considered as viable supply sources. Countries above the 35th percentile are acceptable for the purposes of supplying the general civilian tier, and countries above the 70th percentile are acceptable for the essential civilian tier. The only sources for the defense tier are Canada and Mexico because of their adjoining borders, although countries above the 90th percentile are considered.

The final discounting measure applied is for transportation losses. After the political reliability discounts, estimates of losses of materials sent by ship or air are subtracted from available suppliers by tier.

This process establishes the quantity supplied by tier by year for each material.⁶

VI.4 Stockpile Goals.

The stockpile goals are now calculated for a given material by comparing the imbalances between demand and supply by tier by year. This summation yields an unadjusted stockpile goal. Special Materials Planning Factors are used to adjust stockpile goals if a material has 60% or more of its uses in defense applications or if the United States is 100% import dependent outside of North America. The determination of the final stockpile goals in an iterative process with review by Department of Defense, Department of State, Department of Commerce and Department of Interior as well as FEMA.⁷

VI.5 Annual Materials Plan.

The Annual Materials Plan is a list of stockpile materials proposed for acquisition and disposal developed each year through an interagency committee with similar representation as the group which compiles the stockpile goals. FEMA develops the preliminary list of materials for purchase or sale and the General Services Administration makes the initial assessment that could be purchased or sold without undue disruption of the normal markets for that material.⁸

The list is then reviewed by a number of subcommittees:

- (1) Strategic Implications, determines the impact of changes in defense requirements,

(2) International Economic and Political Impacts, determines the impact on international producers, trade agreements, and foreign producer countries,

(3) Market Impact, determines the impact on commodity markets, and

(4) Economic and Budgetary Impact, examines revenue and cost projections.

After subsequent review of all member agencies and comments are incorporated, FEMA submits the Annual Materials Plan to the National Security Council and the Office of Management and Budget. In fiscal year 1982 the plan was also sent to the Armed Services Committees.⁹ In addition to the purchase and sale recommendations the plan also includes plans for rotation of deteriorating materials and for testing the long term storage characteristics of materials. These last two are important considerations since no major additions to the stockpile have been made since 1959, and no disposals authorized since 1973.

VI.6 Stockpile Considerations.

The national stockpile is not without its critics and although the goals are established through a rigorous process question arise in the areas of methodology, the multiplicity of parties involved and the quantity and quality of stockpiled inventory.

Methodology.

A major restructuring of the stockpile inventory is proposed during the next several years and is necessary because most of the materials were acquired in the 1950's. To fill the goals at 31 March 1982, prices would require approximately \$10 billion. The stockpile inventory contains

approximately \$7 billion of needed materials and its total value is \$11 billion thus there is an excess of \$4 billion which could be used to acquire the needed materials. The main point, however, is the current stockpile methodology leads to an inventory in excess of \$17 billion, and future acquisitions totalling \$7 billion. These levels give rise to questions of the methodology employed by FEMA.

A comprehensive study of the methodology was conducted by the Institute for Defense Analyses and yielded the following conclusions and major sources of error in the process. The scenario of one year warning and three years of war provided the greatest source of error. Defining this scenario to be used for planning purposes is extremely difficult. This difficulty has two resulting effects; (1) the uncertainty is translated by assumptions to the resulting model calculations and (2) the uncertainty of future events imparts a strong conservative bias.

The second major contributor to model error is material usage by industrial sector. Technological trends and substitution change usage rates and influence material requirements. Improvements in this area must be made through expert review by Department of Commerce and Department of Interior commodity experts. A unique problem related to requirements usage is the Department of Defense needs of small quantities by a majority of the output for such materials as titanium, tantalum, and columbium. Changes in weapons technology and these specialized materials should be examined extremely closely.¹⁰

Another area of question in methodology occurs since many of the stockpile minerals by a majority of the defense industries. The government is establishing an empirical data base by weapon system to verify the results of

the macro level analysis done by FEMA and determine the real impact of short-falls of strategic and critical minerals on specific weapons systems. This task is being initiated by the Joint Aeronautical Material Activity at Wright-Patterson Air Force Base. Their initial work will involve only Air Force weapon systems with the eventual expansion to the other services. Eight strategic minerals were identified for the study effort: aluminum, cobalt, nickel, platinum, rehnium, tantalum, and titanium as well as alloys whose primary composition involves one or more of these materials. This particular group was selected because of a combination of factors, including source country instability, National stockpile shortages, and inadequate domestic production or processing.

In fact the task of the Department of Defense is to establish future requirements to meet the broad range of contingencies when material requirements are hidden in a sub-tier contractor for a major weapon system. The Joint Aeronautical Material Activity is studying the requirements for seven defense related strategic and critical minerals. The competition for scarce study resources may preclude significant effort in this area in FY83.¹¹

The study includes current use data by number of pounds per end item and pounds per weapon system in FY83 through FY89. The study will thus gather the data to analyze weapon system dependence on strategic and critical materials and the impact of supply interruption.

Multiple Interest Parties.

Executive Branch.

As cited earlier numerous departments and agencies participate in the formulation of the stockpile goals. The motivation of the

participants differ widely. FEMA has to bring them together in a balanced way. Many of the other participants such as the Department of Defense and the State Department hold powerful positions in the Cabinet and can use their influence to alter stockpile policy. The office of Management and Budget has the overall responsibility to prepare the budget and it is here that stockpile requirements must compete for the scarce dollar resources of the annual budget. The budget item resides in the General Administration line and as such does not appear to have a strong advocate in the Administration or Congress.

Legislative Branch.

Congressional responsibility is fragmented by a number of committees and opinions differ widely by committee members. Strategic Stockpile "policy" is the responsibility of the Committee on Banking, Housing and Urban Affairs. In this committee, led by Senator Proxmire, questions arose concerning the basic assumptions of one year mobilization and three year war. Another of the basic assumptions questioned was the level of civilian austerity during a major conflict. It is recognized that we stockpile for defense needs but the needs for the general civilian add approximately 55% to the stockpile cost - "insurance that nonessential industries will stay open and that civilians will maintain relatively high levels of nonessential consumption."¹²

Senator Schmitt also a member of the committee on Banking, Housing and Urban Affairs of the same committee states an opposing attitude:

"There has been concern experienced with regard to the \$7 billion acquisition costs involved with achieving the

objectives of the national stockpile. However, in a \$2 trillion economy, an investment in this range, made over several years, is not excessive. The United States must remain prepared for whatever emergency may confront us and must, to the greatest extent possible, maintain its self-sufficiency in critical materials. I hope these hearings will provide an added impetus to the fulfillment of the objectives of the strategic stockpile as soon as possible."¹³

During these hearings Senator Hart appeared as Chairman of the Senate Armed Services Subcommittee on Military Cost ^Reduction and Stockpiles since his committee had responsibility over "strategic and critical materials for the common defense." Senator Hart made the statement that, "My appearance at this hearing today should in no way be construed as agreement on my part that the Senate Banking Committee has jurisdiction over strategic stockpile policy."¹⁴

Thus, there is jurisdictional conflict in the Senate which is surely reflected in the House and no appropriate high level advocate in the Executive Branch to bear witness to the necessity for cogent stockpile policy and inventory levels.

Committees whose functions concern stockpiling of strategic and critical minerals include:

Senate Committees

Labor and Public Welfare

Aeronautical and Space Science

Commerce

Public Works

Interior and Insular Affairs

Energy and Natural Resources

Armed Services Committee

Ways and Means Committee

Banking, Housing and Urban Affairs

Commerce Science and Transportation

House Committees

Science Research and Technology

Interstate and Foreign Commerce

Banking, Finance, and Urban Affairs

Interior and Insular Affairs

Science and Astronautics

and others

The Minerals Policy, Research and Development Act, 1980, charged that the administration develop a national policy statement focusing on strategic and critical minerals. Similarly, the vast array of Congressional Committee jurisdictional issues need be addressed to provide the single legislative focal point and single forum for the examination of that policy.

Quality and Quantity of Materials in the Stockpile.

Much of the stockpile inventory was acquired in the 1950's and as such is suspect with respect to its quality because of at least two factors;

one, the material may have deteriorated over the time in storage and two, the technology which produced the materials and the current technology of the use for those materials has significantly changed. Thus, a careful review of the quality and form of the stockpiled materials is required. Specifications for critical materials should be developed and an analysis performed of the characteristics of the inventoried minerals.

Approximately \$4 billion is in excess of the stockpile goals. A comprehensive plan should be developed and implemented to apply this \$4 billion to required minerals either through direct purchase, or barter and exchange. This process would necessarily consider the current market conditions to avoid major disruptions.¹⁵

FOOTNOTES

CHAPTER VI (Pages 44-55)

¹Dr. John Morgan, "Past is Prologue: Strategic Minerals and the Defense Industrial Base," Defense Management Journal, First Quarter 1982, p. 15.

²Federal Emergency Management Agency, Stockpile Report to the Congress, October 1981 - March 1982 (Washington 1982) p. 2-3.

³^{PC}Richard Courter, Highlights of the New Methodology of Estimating Stockpile Goals.

⁴United Technologies Corporation Tech Briefs on Critical/Strategic Materials, 16 November 1981, p. 6-8.

⁵Federal Emergency Management Agency, p. 3.

⁶Courter.

⁷Interview with Richard Courter^D, Oct 1982.

⁸Federal Emergency Management Agency, p. 3.

⁹Ibid.

¹⁰Institute for Defense Analyses, p. 95.

¹¹Dr. John D. Morgan, Global Resource Interdependence and U.S. National Security (Washington, 23 Sep 1982), p. 1-18.

¹²U.S. Congress, Senate, Committee on Banking, Housing, and Urban Affairs, Strategic Stockpile Policy, Hearings (Washington: U.S. Government Printing Office, 1978), p. 1-16.

¹³Ibid.

¹⁴Ibid.

¹⁵President of the United States, National Materials and Minerals Program Plan to Congress, April 1982 (Washington 1982), p.31-32.

CHAPTER VII

PENDING LEGISLATION

There is a major piece of legislation to amend the Defense Production Act of 1950, which was introduced in the House of Representatives on 3 January 1983. This legislation focuses the Congressional interest on the critical and strategic minerals dilemma of the 1980's and focuses on the need for the revitalization of the defense industrial base of the United States.

The Defense Production Act of 1950 provides the basic law upon which to build the necessary programs and incentives to turn around the decline in United States industry. During the 97th Congress a bill was introduced to extend the Defense Production Act for five years and authorize \$6.8 billion to revitalize the defense industrial base. Hearings and mark-up occurred in March 1982 and floor action took place in August and September. An amendment limiting the use of the DPA Title III authorities was adopted which substantially changed the use of these authorizations and thus led to the withdrawal of the bill. An amended Senate bill deleted nearly all changes to the Defense Production Act except a simple six month extension which was finally passed by both houses.⁴ Thus, the Defense Production Act of 1950⁴ ~~is~~ extended until 31 March 1983.

The stage is now set for the introduction in the 98th Congress on a bill to revitalize the defense industrial base of the United States through amendment of the Defense Production Act of 1950 in the form of H.R. 13.

The declaration of policy of the 1950 Act is amended to highlight the nation's reliance upon imports and recognizes international problems. It focuses upon the defense mobilization preparedness efforts in the areas of preparedness programs, industrial base improvements, and expansion of industrial capacity beyond the levels needed to meet civilian demand. These activities are needed to reduce the time necessary for industrial mobilization. Also included in the statement of policy is a charge to the executive agencies and departments to continuously assess the capability of the industrial base to satisfy peace-time requirements and increased mobilization production requirements.

Thus, the new statement of policy crystallized on the industrial base and its efficiency and responsiveness as the major contributor to successful mobilization to provide for national defense and national security.²

A number of amendments to the DPA are included to strengthen the domestic capability and capacity of the industrial base. Financial assistance in the form of loan guarantees, price guarantees, and direct loans is to be directed at modernizing those industries which manufacture or supply national defense materials and which are likely to be required in an emergency or war. Also financial assistance is to be provided for expansion of domestic capability and capacity to produce or process critical and strategic metals, minerals, and materials. One billion dollars are marked to carry out these activities for each fiscal year from FY 1984 to FY 1988.³

This legislation also provides for a national program to train workers in skills to support national defense industries. Grants are provided to

State boards of vocational education based upon a State plan approved by the President. \$250,000,000 is available for these programs each fiscal year 1984 through 1989. A similar grant program is defined for colleges and universities for obtaining and installing modern equipment to train professional, scientific, and technical personnel needed in the national defense industries. \$100,000,000 is available for these grants each fiscal year from 1984 to 1988.⁴

The proposed legislation provides the resources and the direction to foster the resurgence in the defense industrial base. However, the current business cycle and the budget turmoil will probably overcome the intent of this proposed effort. Industry needs some signal with long term implications to invest in modernization and increased capacity. Government can provide that signal and incentive in this type of legislation. The Congress, through the prioritizing of budget resources, can provide a major impetus to the revitalization of the industrial base.

FOOTNOTES

CHAPTER VII (Pages 57-59)

¹Federal Emergency Management Agency, Office of Congressional Relations, Legislation Summary - - 97th Congress, Second Session, Defense Production Act, 7 January 1983, p. 6.

²H. R. 13, Amend to the Defense Production Act of 1950 to revitalize the defense industrial base of the United States. 3 January 1983, pp. 1-18.

³Ibid.

⁴Ibid.

CHAPTER VIII

CONCLUSIONS AND RECOMMENDATIONS

VIII.1 Conclusions.

The United States is at risk for needed strategic and critical minerals. Foreign sources provide large amounts of the strategic materials. A decline has occurred in the industrial base which supported critical and strategic materials production. Initial factors such as limiting land availability for mineral exploration, restrictive environmental regulations and to some extent political interests contributed to the decline of this industrial base. It is not a limitation of exploitable resources in the earth's crust.

A case can be made for substituting other materials for those defined as critical and strategic. However, it is currently uneconomical to do so. In some cases the substituted material requires a cost or performance penalty. In the current recessionary and peacetime climate, industry is inclined to minimize its cost and stay with current materials.

Congress directed the President to create a national materials and minerals policy with leadership at the Executive Office level, to do long range analysis to meet national security, economic and social needs with consultation with the private sector. The President submitted his first plan in April 1982 and it contains a comprehensive policy statement and focused on activities in six major areas. The body of legislation exists to implement these policies and only needs the resources to become effective.

The national stockpile is a viable hedge against supply degradations of critical and strategic minerals. Once again it's resources to fulfill the goals which are needed. There are some facets of the stockpile which could use some attention but it is capable of providing a cushion in emergency situations.

The pending legislation focuses the attention of the Congress on the declining industrial base and provides intent and incentives to industry to do something to improve the situation.

As a result of our investigations of cobalt and titanium we have reached some specific conclusions.

Current domestic cobalt resources will satisfy U.S. needs for at least 56 years, assuming a very liberal constant annual consumption rate of 25 million pounds and no additions to the resource base. However, neither resources nor reserves are sufficiently developed to supply U.S. needs within a reasonable period (18 months) after the on-set of a national emergency.

The national stockpile of cobalt, currently at 53.8% of goal, is only capable of meeting U.S. peacetime consumption for a period of approximately 2 years, assuming a constant 1978 annual consumption rate of 20 million pounds. If the stockpile goal of 85.4 million pounds were achieved, this period could be extended to approximately 4 years. In a national emergency, this would probably allow us sufficient lead-time to bring some of our reserves into full production.

Our analysis of titanium metal revealed that the major uses were in the defense industry and that weapons system performance would be severely degraded if substitute metals were used. The demand for titanium has fluctuated wildly during the past three decades thus industry has been reluctant to expand its capacity facing that uncertain demand schedule.

VIII.2 Recommendations.

In the National Materials and Mineral Policy Act of 1980 Congress required a coherent approach to critical and strategic materials by the Executive Branch of the government.

Likewise, the Congress must attempt to settle its committee jurisdictional disputes and consolidate and focus its attention in this area. The myriad of Congressional Committees fragments the Administration proposals and forces delays in implementation which the Nation can no longer afford. It also diffuses the signals to industry and the true intent and the duration of interest.

Resources must be made available for the research and development leading to substitutes. However, much work has already been accomplished and the focus needs to be in lowering the cost of production of the substitute material and the development of efficient manufacturing processes.

The national stockpile must receive additional resources to become a more viable hedge against the curtailment of critical and strategic materials. A refinement of the methodology to assure the latest technological considerations are included is necessary as well as a focus on those materials whose overall quantity used is small in the context of the GNP but extremely high in relation to the amount consumed in the defense industries.

The pending legislation to amend the Defense Production Act of 1950 should be enacted. This amendment provides a major statement of policy to increase the efficiency and responsiveness of the industrial base. It provides financial assistance and a national program to train workers. This will provide a signal to industry that the government is concerned about the problem of critical and strategic materials and is doing something about it. The current bill has a five year life which provides the commitment to long term that is needed to obtain the appropriate response from industry to invest for the future. The intended resources must be applied to recreate the industrial base which is so rapidly deteriorating.

Some specific recommendations derived from our cobalt and titanium cases are:

The Administration should, on an annual and a priority basis, take advantage to the provisions of Title III of the Defense Production Act of 1950 to expand the nation's productive capacity for cobalt and, hence, lessen our dependency on foreign sources. As an absolute minimum, our cobalt mines should be brought to a level of readiness that would permit full-scale production to begin within 18 months of a national emergency.

In the titanium area the administration should formulate a national policy to insure that sufficient quantities of titanium sponge are available to meet the expected demand. Some effort must be applied to the development of domestic ore resources. Lastly, procurement practices which stabilize demand must be implemented to provide industry the incentive to expand.

APPENDIX A -COBALT

A.1 Introduction.

Cobalt is a silvery gray metal that is usually mined as a by-product of either copper or nickel. It is an essential, nonsubstitutable element in many alloys and an important ingredient in chemical compounds. Cobalt is a vital alloying element in the aerospace and electrical product industries. As an alloy, cobalt yields high heat resistance, high strength, high wear resistance, and superior magnetic properties. Major uses of cobalt include cutting tools, jet engine parts, electrical devices, permanent magnets, catalysts, paint pigments, and paint dryers.¹

The U.S. is the world's largest user of cobalt and annually consumes approximately one-third of total world production. The aerospace industry is the largest U.S. user of cobalt. In fact, aircraft engine and parts production accounted for approximately 45 percent of U.S. demand in 1980. The electrical product industries accounted for approximately 15 percent of U.S. demand in 1980 and an additional 15 percent was used in the production of metal cutting and mining tools.²

Cobalt has not been mined in the U.S. since 1971. Hence, this country is dependant upon foreign sources for its total supply of new cobalt. The primary foreign sources for U.S. cobalt are Zaire and Zambia, both of which are very politically volatile. Thus, the U.S. remains vulnerable to supply disruptions such as those which occurred in 1978. This vulnerability would be even more grave in the event of war with the U.S.S.R.³

A.2 Vulnerability.

Cobalt is one of the 11 mineral groups found in the National Stockpile which were designated as "priority materials" by the Reagan Administration in March 1981. Due to a number of different circumstances that have occurred in recent years, it also represents an excellent example from a case study standpoint of U.S. vulnerabilities in strategic non-fuel minerals.⁴

Until 1980, the U.S. had not made a stockpile purchase for over 20 years. In fact, from 1968 until 1976, the U.S. government was each year selling six to nine million pounds of cobalt, almost one half of the annual domestic consumption rate. It had also been widely announced prior to 1976 that the entire stockpile would be disposed of. Sales were suddenly stopped in 1976 and a new policy of more than doubling the then remaining cobalt stockpile was announced. This policy reversal caused an almost immediate domestic shortage of cobalt to occur. U.S. industries which had become partially dependent on the U.S. government stockpile as a supplier suddenly had to seek new sources of supply elsewhere, and to some extent were now in competition with the government stockpile for the available holdings on the world market.⁵

Shortly thereafter, in both 1977 and 1978, Katangan rebels living in Angola crossed the border into Zaire and invaded Shaba province. In May 1978 they attacked the city of Kolwezi, center of the copper and cobalt industries. Shaba province at that time alone was providing more than one half of both the world's and U.S. cobalt imports and accounted for more than one-third of the world's known on-shore reserves of cobalt. While this

invasion lasted for only a few weeks and there was only minimal damage inflicted on the mines or equipment, the overall disruption was much more severe. The invasion resulted in the massacre of civilians including some of the foreign mining technicians. This resulted in an exodus of most of the expatriate technicians needed to operate and maintain the mining facilities. The net effect was that while there was no really severe shortage of either copper or cobalt, the producer price of copper increased by 30 percent and that of cobalt to 300 percent. Cobalt went from \$6.40 per pound in early 1978, to over \$25.00 per pound by the end of the year, with occasional spot prices of up to \$50.00 per pound reported on the open market. The anticipated shortages together with the speculative buying and panic hoarding all contributed significantly to the price rise. These incidents occurring as they did on the heels of the U.S. Government policy reversal of selling from buying for the national stockpile, only further served to aggravate a deteriorating situation.

Another factor in the vulnerability of cobalt has been that of transportation. Since 1975 when the civil war in Angola broke out, the transportation of cobalt through Angola from Shaba province has been interrupted. The Benguela railroad which had served as the main transportation route for GECAMINES (General des Carriers et des Mines) the nationalized Zaire mining industry, has been repeatedly attacked in Angola by UNITA (National Union for Total Independence of Angola) guerrilla insurgents. As a result, GECAMINES has used several alternate routes including a rail line through Zambia, Zimbabwe and Botswana to ports in South Africa, however,

continued logistical and political problems associated with these routes have continued to plague shipments and as a result, since 1978 Zaire has had to rely on air transportation for the significant percentage of its cobalt exports.⁶ Although at the high prices previously enjoyed by cobalt, air shipment was economically feasible, the same is not true for copper. It is imperative, therefore, that the land transportation lines be maintained since if copper could not be exported, production of copper would cease and along with it the byproduct, cobalt.

The byproduct relationship of cobalt to copper and nickel has been a significant factor in the supply and demand relationship and must also be considered as a vulnerability. Approximately 95 percent of cobalt is obtained as a byproduct of copper and nickel. The continued depressed prices of these two metals in the early 1970s served to inhibit production even when the demand for cobalt suddenly expanded in the mid-1970s. Since the percentage of cobalt to either copper or nickel is relatively small, usually less than three percent, even a significant increase in comparative cobalt prices, represents only a minimum proportionate value increase to the total value of a mine's output. Cobalt, at a reduced price, is therefore susceptible to insufficient mine capacity production resulting from a lack of expansion of either copper or nickel operations. Only when the demand, and correspondingly, the price of cobalt is raised sufficiently, does it become a co-product rather than a byproduct. During the economic recession of 1974 to 1975 the depressed market for both copper and nickel also affected cobalt. When the demand for cobalt suddenly increased in 1975 through 1978, there was not a proportionate

increase in the demand for copper and nickel hence this byproduct relationship inhibited the production of cobalt. During the same period, Zairian production problems further aggravated this situation. Government pressures to increase rather than decrease copper production in order to compensate for low prices resulted in wasteful mining and processing practices by GECAMINES. In order to minimize production costs, they exploited their richest copper deposits without regard to their longstanding development. This, together with shortcuts in processing, reduced the rates of copper recovery but also resulted in substantial losses of cobalt. A CIA analysis attributes this loss to some 25 million pounds of cobalt during 1975-1977 thus contributing to the temporary cobalt shortage.⁷

The possibilities of an embargo, cutoff, or the vulnerability to an OPEC type cartel have also been hypothesized for cobalt. It is true that the major land suppliers are both central African lesser developed countries, of close geographic proximity. Both Zaire and Zambia, which together in 1979 produced 73 percent of the world's supply of cobalt, could under the right circumstances form a monopoly. However, unlike many of the OPEC countries which did not need the foreign capital, both Zaire and Zambia are in serious economic conditions and rely heavily on their exports for the foreign capital needed. In addition, unlike in 1977 and 1978 when there were limited alternatives, there are now substitute items and other producers attracted to the market by the 1979 prices that are willing to step in if the price once again is right. Both of these factors would serve to preclude an intentional cutoff of prolonged duration. Of more concern would be an externally directed

cutoff through actions or transportation delays imposed by neighboring countries or insurgents. In fact, contrary to several predictions of only two years ago, both countries have announced intentions to increase production and rather than colluding, appear to be in competition. The sale by Zaire of cobalt for the U.S. stockpile in 1981 was at the rate of \$15 per pound, significantly below the then prevailing producer price quote of \$20 per pound. In October 1982 Zaire again offered to sell the U.S. 2000 tons of cobalt at a price of \$5.80 per pound while the current price had been \$12.50 per pound since February 1982.⁸ Zaire's intention may have been an effort to protect its market share from inroads by Zambia the world's second largest producer, however, it also had a detrimental effect on any plans U.S. private industry may have had for further domestic cobalt development. It also tended to discourage efforts toward producing substitute materials in this country. The low grade domestic ore deposits cannot compete with the high grade deposits found in central and southern Africa where abundant power and a cheap labor supply are also available.

Another consideration that must be taken in trying to overcome our foreign dependence, and thus our vulnerability is one of timing. Those U.S. cobalt reserves that are the most exploitable from a mobilization standpoint are estimated at being able to supply up to 10 million pounds annually for 10 to 15 years. In the absence of any new domestic ore discoveries, or technology breakthroughs in substitute alloys which will provide an equal level of performance, it could be argued that those reserves should only be exploited during a time of extreme emergency. Obviously, if we were to

subsidize production on these facilities today in order to maintain an industrial base capability; if a national emergency were to occur in 10 to 15 years time, we would be in infinitely worse shape with our reserve then virtually exhausted. The same philosophy helps to explain U.S. reluctance to develop an independent energy policy. Even at the peak of OPEC imposed oil prices, we were willing to buy rather than cutoff our dependence and thus more rapidly exhaust our own supplies.

In one vulnerability scenario, a peacetime resources war is projected in which the Soviet Union attempts to deny critically needed materials to the U.S. and its allies by direct market intervention or more likely by extending its political influence on the mineral producers. This too is not likely to happen because of the fact that in most materials, the Soviet Union is self-sufficient and would have to either purchase those shares it intends to deny to the west, or otherwise reimburse the cooperating country for their loss of revenues in order to maintain an agreeable relationship with that country. In the case of cobalt, the opportunity is there since Soviet influence is considerable in Zambia, and in several of the other countries surrounding Zaire, however, other than keeping the area in a turmoil, there does not appear to be any attempts to influence the cobalt market.

After the 1978 invasion by Katangan rebels, it was widely reported that the Soviets had purchased large supplies of cobalt just prior to the invasion. Official U.S. Government sources, however, report that there is no evidence that this really occurred. While the Soviets do import cobalt, their source has been primarily Cuba. Obviously, during a period of hostilities,

Soviet interest in our most important raw material source nations are a major concern, and the likelihood of their attempts at causing a disruption if given the opportunity to do so should certainly not be discounted.

It has also been alleged that anticipated purchase for the U.S. stockpile will have a negative effect by keeping prices high, however, the reverse has actually occurred. The mere fact that the stockpile exists seems to serve a psychological hedge against any significant attempts to raise prices, or threats of an embargo or cutoff.

One further factor that has lead to foreign dependency for cobalt has been the environmental legislation. In order to exploit those domestic mines previously in production it would require clean up at the sites from previous poor mining practices and considerable investments just to meet the new environmental protection laws. If the Blackbird mine had reopened in 1981, the Noranda Mining Company was seriously considering processing the cobalt overseas because of the environmental protection law. The net result therefore would not have eliminated our vulnerability.

The world is in no danger of running out of cobalt. Speculative resources in the U.S. and the rest of the world amount to many billions of pounds. As long as industrialized nations are willing to pay prices that make cobalt production economically feasible, supplies will be abundant. However, the largest proportion of world resources are located in the politically unstable countries of Southern Africa. Hence, even in the absence of war, the world's industrialized nations should expect to experience supply disruptions from time to time.

In the immediate future, there is little likelihood that U.S. cobalt supplies will be interrupted by an embargo, cutoff or cartel type activities initiated by a supplier. The greatest vulnerability that the U.S. faces is that of the transportation nets from the suppliers. With the greatest percentage of U.S. imports still coming from central Africa, the land transportation nets are the most precarious. The 1600 mile long combination rail-barge-rail line from Kolwezi to the port of Matadi at the mouth of the Zaire river runs through territory that since 1975 has been under insurgent or other hostile forces controls. The other routes terminating in South Africa are even longer and subject to the same disruptions. Transportation of materials on these routes frequently takes one and a half months. Although the sea lanes pose no immediate problems during peacetime or even intensified cold war conditions, this transportation net would be extremely vulnerable during time of war. Other than Canada which provides less than 10 percent of U.S. cobalt imports all the other major U.S. suppliers are thousands of miles across the ocean.

A.3 Domestic Resources and Reserves.

Any discussion of resources and reserves requires and understanding of the definition of these words. The definitions shown below have been agreed to by both the U.S. Bureau of Mines and the U.S. Geological Survey.

Resource - A concentration of naturally occurring solid, liquid, or gaseous material in or on the Earth's crust in such form and amount that economic extraction of a commodity from the concentration is currently or potentially feasible.⁹

Reserve Base - That part of an identified resource that meets specified minimum physical and chemical criteria related to current mining and production practices, including those for grade, quality, thickness, and depth. The reserve base is the in-place demonstrated (measured plus indicated) resources from which reserves are estimated. It may encompass those parts of the resources that have a reasonable potential for becoming economically available within planning horizons beyond those that assume proven technology and current economics. The reserve base includes those resources that are currently economic (reserves), marginally economic (marginal reserves), and some of those that are currently subeconomic (subeconomic resources). The term "geologic reserve" has been applied by others generally to the reserve-base category, but it also may include the inferred-reserve-base category; it is not a part of this classification system.¹⁰

Reserves - That part of the reserve base which could be economically extracted or produced at the time of determination. The term reserves need not signify that extraction facilities are in place and operative. Reserves include only recoverable materials; thus, terms such as "extractable reserves" and "recoverable reserves" are redundant and are not a part of this classification system.¹¹

In August 1982, the Office of Resources Preparedness, Federal Emergency Management Agency, published a detailed assessment of domestic resources and reserves of cobalt. That assessment is provided below.¹²

Although domestic mine production has not occurred since 1971, domestic identification resources, i.e., cobalt concentrations that are technically recoverable, are extensive. The U.S. Bureau of Mines has identified resources estimated at 1.4 billion pounds. The portion of identified resources that can be economically extracted, the reserve base, was estimated in 1980 to be 209 million pounds. At prices ranging up to \$25 per pound, it is economically feasible to extract 72 percent of this reserve base. These figures are not static and vary with price, exploration, and technology.

The price of cobalt did not attract domestic resources development until 1978. In that year, the price of cobalt rose from \$6.85 per pound to \$25 per pound, and remained at that level until February of 1981. Downward price adjustments were made several times since then. As of February 1982, the price was approximately \$15 per pound. The continuation of these relatively high prices has encouraged planning for the development of domestic higher grade deposits.

Plans to reopen cobalt mines in Blackbird, Idaho, and Fredericktown, Missouri, to develop a mine in the Gasquet Mountains area of California, and a cobalt recovery project have been considered by Noranda, Hanna, Anschutz, California Nickel, and AMAX mining companies, respectively. In fact, the companies have prepared

extensive mining and refining feasibility and cost studies, developed much of the necessary mine infrastructure, and obtained many of the necessary environmental permits.

By 1985 approximately 9 million pounds of cobalt could be produced from these sources. By 1990, an additional 5 million pounds could be produced annually. According to a recent Bureau of Mines study, at current cobalt, copper and nickel prices, over half of domestic requirements in 1990 could be met with existing domestic production potential.

Domestic cobalt production plans, however, remain tentative. Domestic cobalt mining and refining is characterized by large fixed investments and high risk exposure. To produce cobalt domestically from the higher grade domestic resources, a minimum investment of \$100 million is required for a two million pound per year operation. Because domestic cobalt production is economically feasible only with the higher prices of recent years, the possibility of further major price reductions renders these investments very risky. Zaire has the capability to lower the world price below the domestic break even point and still make a profit over their production costs.

Domestic producer plans for refinery investment are also tentative. High purity cobalt metal refining investment costs represent approximately 66-75 percent of total investment costs. The required investment for extracting the ore represents the remaining 25-33 percent. If domestic producers commit their resources to extraction and choose not to invest in a refinery, but to have the cobalt refined overseas, or to produce a concentrate, U.S. strategic vulnerability remains. Overseas refining imparts much the same supply risks as non-Central African supply does today. The major cobalt refiners, Japan and Western Europe, are also major cobalt consumers. If a serious disruption of Central African cobalt supply occurred, ^{THE} U.S. could expect these countries to meet their domestic needs before the needs of the export market.

A.4 Foreign Resources and Reserves.

The following assessment of foreign resources and reserves was published by the Bureau of Mines.¹³

Much of the world's identified resources are in the form of lateritic nickel ores in tropical regions, such as the Philippines, Indonesia, and New Caledonia. Australian production from laterites has become an increasingly significant source. Nevertheless, most cobalt currently comes from sulfide and oxide deposits in Zaire, Zambia, Finland, and Canada. Expansions were planned in 1979 in each of these countries. Moroccan deposits may become more significant in the future. Moroccan cobalt is mined as the

principal product, and rising cobalt prices may result in production of previously uneconomic material. However, the best long-term prospect for abundant supplies may be the development of cobalt-bearing manganese nodules on the Pacific Ocean floor.

Table 1 shows the areas possessing identified resources of cobalt. Speculative resources in both the United States and the world amount to many billions of pounds more, but cobalt mining is only likely if the associated metals, such as nickel, copper, iron, lead, zinc, and silver are in high demand and are mined. In terms of estimated reserves, Zaire ranks first, followed by Zambia, the U.S.S.R., Cuba, the Philippines and New Caledonia.

To provide current resource information, the Bureau of Mines maintains a data bank under its computerized Minerals Availability System (MAS) in which reserve and resource data on cobalt and other mineral ore deposits in the United States and throughout the world are being compiled.

Table A-1 - World Cobalt Resources¹⁴

(Million Pounds)

	<u>Reserves</u>	<u>Other¹</u>	<u>Total</u>
North America:			
United States	0	1,700	1,700
Canada	60	500	500
Cuba	400	2,100	2,500
Total	<u>460</u>	<u>4,300</u>	<u>4,760</u>
Europe:			
Finland	40	10	50
U.S.S.R.	500	50	550
Total	<u>540</u>	<u>60</u>	<u>600</u>
Africa:			
Botswana	60	10	70
Morocco	100	50	150
South Africa	50	10	60
Zaire	2,600	500	3,100
Zambia	800	500	1,300
Total	<u>3,610</u>	<u>1,070</u>	<u>4,680</u>
Oceania:			
Australia	100	550	650
New Caledonia	200	650	850
Philippines	400	50	450
Total	<u>700</u>	<u>1,250</u>	<u>1,950</u>
World Total (land-based) ²	5,300	6,700	12,000
World Total: Seabed nodules ³	0	500,000	500,000

¹Derived in consultation with the U.S. Geological Survey.²Data may not add to totals shown because of independent rounding.

³Based on Bolser's paramarginal resource estimate of 76 billion dry short tons of seabed nodules and the NREB-323 estimate of average nodule composition of 1% copper, 0.35% cobalt, and 24% manganese. (F. Bolser, *Manganese Nodule Resource and Mine Site Availability*, Ocean Mining Administration, U.S. Department of the Interior, August 1976, p. 28; National Materials Advisory Board, NREB-323, 1976).

A.5 International Source - Deep Sea Mining.

It has been known that the oceans which cover two thirds of the earth's surface, contain vast resources, enough to supply man's needs for many hundreds of years to come. The inhospitable ocean environment together with the lack of suitable technologies has in the past hampered man's ability to discover and exploit these resources.

A promising source is the ocean bottoms which at depths of from 10,000 to 20,000 feet are littered with extensive deposits of nodules containing high grade ores of Manganese, Copper, Cobalt and Nickel, with traces of Vanadium and Molybdenum.

The following assessment of international sources of cobalt was published by Federal Emergency Management Agency in August 1982.¹⁵

Deep-sea manganese nodules are a significant, long-term potential source of cobalt. Although nodules would not provide the supply security of the domestic source, substantial diversification of supply could result. The ocean floor nodules range from pea to baseball in size and contain significant quantities of cobalt averaging (0.235-0.35 percent), nickel (1 percent), copper (1 percent), and manganese (24 percent). Potential annual recovery is estimated at 40 million pounds of cobalt, 337 million pounds of nickel, 270 pounds of copper and 3750 million pounds of manganese.

...the commercial viability of deep seabed mining is uncertain. Production could begin, according to industry sources, as early as 1990, but is unlikely until 2000.

A.6 Production and Substitutes.

A.6.1 Production.

Cobalt has the desired properties of hardness, and resistance to corrosion, heat and abrasion. It is used in jet engines, cutting tools, drill bits, wellhead valves, and as a catalyst for petroleum hydrogenation.

Domestic resources of cobalt in Idaho, Minnesota, Missouri and California could in the future supply more than one half of the annual domestic consumption rate, assuming the peak usage rates of 1978 through 1980. In 1979, because of the dramatic price increases that occurred during the previous year, both the Anschutz Mining Co., which took over the Madison Mine near Fredicktown, MO., and the Noranda Mining Company, which operates the Blackbird mine in central Idaho, invested more than \$40 million gearing up for production which together with other processing industries could produce up to 10 million pounds of cobalt per year. The Madison Mine was projected to have a 10 year life with an annual capacity in excess of 2 million pounds with copper, lead and nickel as byproducts. Late in 1981, Anschutz was forced to cut back on their staffs to a care and maintenance status. Similarly, the Noranda Mining Company which had conducted extensive development at the Blackbird Mine which had a reported capacity of up to 6 million pounds, also cut its workforce in half at the site. Early in 1981, Noranda had taken an option on land near Blackfoot, Idaho approximately 150 miles southeast of the Blackbird Mine. At this site they had planned to build a plant to process the cobalt concentrates produced at the Blackbird Mine, recovering the cobalt through a leaching, solution extraction and electrowinning process. That same

year, however, due to the increasingly depressed market and with no assurances of governmental financial assistance, these plans were delayed. It would require several years and considerable investment to modernize and repair these facilities in order to bring them to a fully operational status. It would also require the price of cobalt to remain about \$25 per pound for a sustained period on the world market in order to make it economically practical to operate these plants under peacetime conditions. The likelihood for this to occur is minimal since Zaire could economically produce cobalt at less than \$5 a pound and would in all probability reduce its prices rather than lose the U.S. as a customer. There are also several domestic facilities that are involved in cobalt recovery from various sources. Almost one million pounds of cobalt was recovered in 1981 from imported matte by AMAX Inc. at the Port Nickel refinery at Braithwaite, LA. This firm has also made proposals to FEMA seeking government purchase guarantees for the National stockpile of high grade cobalt produced at their facilities. One foreign company also operated a plant located in Laurinburg, NC to produce extra fine cobalt powder.

In the early 1970s Zaire started development of two major copper/cobalt projects, the Tenke Fungurume and the P2 expansion of GECAMINES western group operations. The prospects of these additional facilities becoming operational as an inexpensive cobalt source served to discourage both U.S. and foreign competition and at the same time assisted Zaire in maintaining a virtual cobalt monopoly. These facilities were dependent on the construction of the new Inga Shaba power transmission lines which has been plagued by work delays although work is finally scheduled to be completed in

late 1983. Meanwhile the Tenke Fungurume project was halted in 1976 and if eventually continued will be at a reduced output scale of 4.4 million pounds annually rather than the ambitious 13 million pounds originally planned. The expansion of the P2 smelter and refining complex at Kolwezi has also remained uncompleted since 1978, as Zaire has had to divert capital towards servicing its \$6 billion foreign debt. Depressed copper prices have also affected these expansion efforts.

Zambia has also greatly expanded its facilities since 1978. In 1981 Zambia's two major copper and cobalt producers merged into one company called Zambian Consolidated Copper Mines Ltd., however, the company is still controlled by the government. In spite of successive strikes during 1981 the company was able to produce 3,640 tons of cobalt concentrate, an amount excessive to the company's capability to refine. Much of this was stockpiled locally to be refined upon the completion of a roast-leach-electrowinning plant at Rokana in late 1982. At Chambishi a vacuum refining furnace was being installed which was expected to produce cobalt suitable for superalloy production.

The increased prices after 1978 caused an expansion of production facilities in a number of other countries which lowered prices due to competition. This in turn lessened the likelihood of a cutoff of cobalt supplies for the U.S. because multiple suppliers were in the market.¹⁶

From the defense standpoint, cobalt is used widely in a variety of end products. In electrical equipment and supplies cobalt additions raise the saturation magnetization and Curie temperatures to higher values than other

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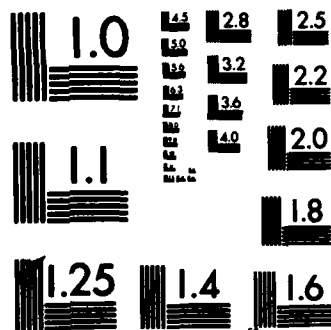
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ferromagnetic materials. These cobalt containing magnets are used in telecommunications, magnetic couplings, meters, loudspeakers and permanent magnet motors. The primary use of cobalt is in superalloys in jet engine parts which are subject to stress at high temperatures up to 1,600 F, under low stress conditions (10,000 ppsi) and moderate stress (20,000 ppsi) up to 1,800 F, however, it will breakdown under high stress conditions at over 1,900 F (30,000 ppsi) for several hours. Other uses not as apparent include high strength and abrasion resistant tools, various types of equipment, in points and related products, in chemicals and various medical uses.

A.6.2 Substitutes.

The invasion of the Shaba province did serve to make the U.S. become more aware of its economic dependence and the associated consequences that could result from even a short term cutoff of cobalt. It had the added benefit of forcing development or resurrection of substitute items in order to minimize future vulnerability.

A net effect has been that within two years under peacetime conditions, that U.S. was able to significantly reduce its demand and consumption of cobalt. It is difficult to assess the degree or proportionate percentages that can be attributed to either the current recession or economic measures taken, however, the import and consumption rates of cobalt have dropped significantly. From imports of 19 million pounds and consumption of

almost 20 million pounds in 1978, imports had declined to 15.6 million pounds in 1981 and 13 million pounds through November 1982. During the same two years, from these import totals, 2.9 million pounds and 2.3 million pounds respectively were for the national stockpile.

Even though the 1978 cutoff was of relatively short duration, once U.S. industry had determined not to have the situation repeated, despite the eventual lowering of prices, the economizing measures continued. During 1981 the producer price of cobalt was reduced 3 times from \$25 per pound down to \$17.26 by year end. Spot prices had also dropped to a low of \$9.50 per pound during the fall of 1981. These price cuts resulted from the reduced demands for cobalt, a buildup of producer inventories and competitive efforts to counteract price discounting and substitution. Although Zaire initiated the price cuts, once the market took over, Zaire did not respond fast enough and thus lost a significant part of its share of the U.S. market in 1981. Zaire's imports of cobalt to the U.S. in 1980 was 6.238 million pounds compared with only 4.176 million pounds in 1981.

The following tables show U.S. consumption of cobalt by end use for the years 1980 and 1981 and by form from 1977 to 1981. While conservation measures account for some of the reduction in consumption rates, of significance is the drop that occurred in use of cobalt in both superalloys and magnetic alloys that occurred in 1981. While final figures are not yet available for 1982, domestic consumption rates through November 1982 were reported at 8.5 million pounds, which would further reduce consumption rate to less than one half of what it was in 1978.

TABLE A-2 - U.S. Consumption of Cobalt, By End Use

(Thousand Pounds of Contained Cobalt)

End Use	Quantity	
	1980	1981
Steel:		
Stainless and heat-resistant-----	47	35
Full-alloy-----	116	141
High-strength, low-alloy-----	W	W
Tool-----	321	170
Superalloys-----	6,285	4,195
Alloys (excludes alloy steels and superalloys):		
Cutting and wear-resistant materials-----	1,344	1,076
Welding materials (structural and hard-facing)-----	620	488
Magnetic alloys-----	2,267	1,687
Nonferrous alloys-----	150	131
Other alloys-----	210	123
Mill products made from metal powder-----	W	W
Chemical and ceramic uses:		
Pigments-----	282	329
Catalysts-----	1,656	1,279
Ground coat frit-----	482	441
Glass decolorizer-----	40	40
Drier in paints or related usage-----	1,331	1,378
Feed or nutritive additive-----	75	58
Miscellaneous and unspecified-----	95	109
Total-----	15,321	11,680

W-Withheld to avoid disclosing company proprietary data; included with "Miscellaneous of unspecified."

¹Cemented and sintered carbides and cast carbide dies or parts.

TABLE A.3 - U.S. Consumption of Cobalt, By Form
(Thousand Pounds of Contained Cobalt)

Form	1977	1978	1979	1980	1981
Metal-----	11,547	12,823	12,006	10,825	7,450
Oxide-----	426	467	704	441	557
Purchased scrap-----	507	1,036	1,170	1,183	972
Salts and driers-----	3,778	5,399	¹ 3,254	¹ 2,475	¹ 2,421
Other-----	319	269	268	397	280
Total-----	16,577	19,994	17,402	15,321	11,680

¹Chemical compounds (organic and inorganic) other than oxide.

Of further significance has been the relatively orderly pace of which this reduction has taken place. Allowances must be made for a reasonable period after the 1978 cutoff in which the U.S. adopted a wait and see attitude in trying to determine whether or not the situation would be of long duration. This delayed response time would not have occurred during a time of national emergency in which mobilization was taking place, hence the ability to adjust would therefore probably be much quicker. Even so, when it appeared that the price of cobalt would continue to remain high, conservation and other substitution measures were taken.

"In non critical uses, such as in magnets, steps were taken to replace alnico (aluminum, nickel, cobalt) magnets with ferrite and ceramic materials which contained no cobalt, and by greatly reducing the cobalt content of samarium magnets. The Bell System, one of the largest magnet consumers in the world is replacing the 24 percent cobalt magnets in its telephone receivers with a new magnetic material called Chromonder III containing only one half as much cobalt. Since 1978 there has been an overall 50 percent decline in the use of cobalt in magnets.

In high speed tool steels which have 15 percent of the cobalt market, Crucible Steel has already developed two commercially available cobalt-free alloys REX 20 and REX 25. The alloys substitute powdered tungsten and molybdenum for cobalt in a new forming process called hot isostatic pressing. In drill bits, the Hughes Tool Company is replacing cobalt with boron, saving two tons of cobalt per month.

Even in jet engines where the role of cobalt in superalloys had until now gone unchallenged, Pratt and Whitney engineers have developed cobalt-free alloys INCO 713 and 718 by substituting nickel molybdenum and aluminum for cobalt. This move alone will reduce the cobalt used in the F-100 engine from 900 plus pounds to 400 plus pounds. Industry materials scientists indicate that cobalt rather than nickel was selected for use in turbine engine blades in the early 1960s primarily because at that time it was cheaper than nickel.

With relative prices now having shifted sharply in nickel's favor, and cobalt supplies now more vulnerable to interruption production, engineers

have begun designing cobalt out of their products. Pratt and Whitney, the world's single largest user of cobalt, plans to reduce cobalt consumption by 50 percent over the next few years. This cobalt example illustrates yet another point, the new nickel-molybdenum-aluminum alloy now being introduced into turbine blades was patented in the 1950s. So-called new technologies such as composites, rapid solidification techniques, hot isotatic pressing and powder metallurgy that are permitting engineers to replace traditional strategic metals with new materials are actually 20 to 30 years old. There is an array of on the shelf technologies that can quickly find their way into commercial products given the economies to do so. Although it takes about 10 years to develop a truly new technique or alloy, the research and development for many of these innovative approaches to materials substitutes have already been done."¹⁸

Nickel is substituted for cobalt in some uses with little change in end-product characteristics. Cobalt may also be substituted for nickel. For example, in 1969 during the nickel-mining strike in Canada, cobalt was effectively used in electroplating. However, the fact that nickel is not now generally used as a substitute for cobalt even though it is one-eighth as expensive is evidence that use of nickel would result in a sacrifice of important properties or characteristics of end products made with cobalt. The current trend is toward greater use of alloys with less cobalt, rather than elimination of cobalt altogether in the alloy. This is true in the fields of both hard-facing and wear-resistant applications, and superalloys. One example is the substitution of nickel-base Inconel 718 for the L605

cobalt-base alloy in a rocket-propulsion system application. In certain cases, the alloys Udimet-500 or Udimet-700, containing about 18% cobalt each, might be replaced with nickel-base alloys with similar properties, but containing less cobalt. Certain iron-base, heat-resistant alloys, such as N-155, can be substituted for cobalt-base materials, such as X-40 (HS-31), FSX-4F4, etc., in turbine applications. In aircraft turbine applications, Alloy 713C (no cobalt) might replace Waspalloy with 13% cobalt. A problem to be noted in any substitution is the replacement of one expensive and scarce material with another that may become equally or more scarce and expensive. Replacing cobalt-bearing alloys with alloys relatively high in columbium and tantalum is a good example in the superalloy field.

Substitutes for cobalt as a catalyst or as a dryer in paints are usually not effective. In dryer applications, manganese and lead each can act either as a complement or as a substitute. In catalytic applications, molybdenum and aluminum are complements, and nickel and tungsten together are substitutes for cobalt (7). However, use of nickel in petroleum catalysts reduces octane and requires higher pressures to be effective.

The properties that cobalt imparts to permanent magnets exceed those that can be contributed by other elements. Any substitution for cobalt results in loss of weight advantage or other physical properties. Nevertheless, ceramic magnets, which are made from barium and strontium ferrite, are potentially strong competitors. Because ferrite magnets are relatively inexpensive, they are used in a number of automotive applications, and because of price and availability considerations, they replaced Alnico

magnets in auto loudspeakers in 1980 models. However, because of the drive to conserve space and weight in automobiles, cobalt-rare-earth magnets may eventually replace ceramic ferrite magnets. In comparison with Alnico magnets, a net cobalt savings of 30% can be achieved by use of cobalt-rare-earth magnets. In magnetic usage, demand is more sensitive to price than in other uses such as superalloys, thus rendering replacement more likely.

No satisfactory substitutes have been developed for use of cobalt as a binder for carbides. However, with further experimentation, molybdenum-based tool steels, which can contain up to 12% cobalt, may achieve the performance characteristics of cemented carbides, or an equally suitable binder may be found. Recent advances in powder metallurgy have afforded an opportunity to attain competitive performance levels. With research, it may also be found that alloys with a base of nickel, vanadium, chromium, or tungsten can be developed that have properties equal or superior to those of alloys containing cobalt.

Another potential source of cobalt nickel and other critical metals is unrecycled superalloy scrap and industrial waste. It is estimated that annually, uncollected or downgraded superalloy scrap contains up to 6 million pounds of cobalt, 53 million pounds of nickel, and 22 million pounds of chromium. Research is being conducted to assess the use of electrolytic techniques to produce cobalt-nickel master alloys from recycled materials.²⁰

The major obstacles to substitution are the economics, the relative degree of effectiveness of the substitute product, and the potential for long duration cutoff or continued high prices of the basic material.

Because of extensive substitution and conservation measures in reducing waste, preforming and recycling that has occurred within the past two years, the demand for cobalt is not expected to increase above previous demands unless once again the price is reduced and remains stable. Barring prospects for any form of U.S. government subsidies for further exploration and development of cobalt resources, or research and development for additional substitutes, prospects for future cobalt demand boils down to the question of economics. It should be noted that in 1981, at the same time the government was purchasing 5.2 million pounds of cobalt for the national stockpile; it also exported the equivalent of 834,000 pounds of cobalt metal in unwrought cobalt metal, waste and scrap to 41 countries.

A.7 National Stockpile-Cobalt.

Cobalt is held in the national defense stockpile under authority of the Strategic and Critical Materials Stock Piling Act of 1946. The current stockpile goal for cobalt is 85.4 million pounds.²¹ In June of 1981, the U.S. purchased 5.2 million pounds from Zaire.²² Therefore, our national stockpile now contains about 46 million pounds of cobalt.²³ Hence, a shortfall of approximately 39.4 million pounds remains. The 46 million pounds is 53.8% of the stockpile goal. At the existing level of 46 million pounds, the stockpile could meet U.S. peacetime consumption for 2.3 years based on reported consumption for 1978 of 19.994 million pounds; for 2.6 years based on reported 1979 consumption of 17.402 million pounds; for 3 years based on reported 1980 consumption of 15.321 million pounds; and for 3.9 years based on reported 1981 consumption of 11.680 million pounds.

(NOTE: Annual consumption figures were taken from the 1981 minerals yearbook).

Based on the above data, it is clear that the stockpile, at the current level, provides adequate protection against any short-term supply disruption from foreign sources. However, this same conclusion could not be drawn if the supply disruption were of extended duration. Indeed, the situation becomes very bleak when viewed in terms of wartime requirements increasing to 150 to 200% of normal requirements.

FOOTNOTES -APPENDIX A

¹United States Department of the Interior, Bureau of Mines, Cobalt - A Chapter from Mineral Facts and Problems, 1980 Edition, Preprint from Bulletin 671 (Washington: U.S. Government Printing Office, 1980), p. 1, 4.

²Federal Emergency Management Agency, Office of Resources Preparedness, Alternative U.S. Policies for Reducing the Effects of a Cobalt Supply Disruption--Net Economic Benefits and Budgetary Costs (Washington: August 1982), p. 4.

³United States Department of the Interior, Bureau of Mines, Cobalt Availability - Domestic, A Minerals Availability System Appraisal, Information Circular 8848 (Washington: U.S. Government Printing Office, 1981) p. 1-2.

⁴Kilmarx, Robert A. "Toward a Coherent U.S. Policy on Strategic Minerals: A Guide to the Facts," Significant Issues Series, Vol. IV, No. 3 (Washington, D.C.: Center for Strategic and International Studies, Georgetown University, 1982), p. 3.

⁵Bureau of Mines, Cobalt - A Chapter from Minerals Facts and Problems, 1980 edition, p. 1.

⁶Ibid., p. 10.

⁷U.S. State Department Bureau of Intelligence and Research, Cobalt Prospects: Trouble Ahead, Report No. 1375, May 12, 1980, p. 5.

⁸"A Cobalt Price War May Endanger U.S. Security", Business Week, November 8, 1982, p. 58-59.

⁹United States Department of interior, Bureau of Mines, Mineral Commodity Summaries 1982 (Washington: January 1982), p. 178.

¹⁰Ibid., p. 179.

¹¹Ibid.

¹²Federal Emergency Management Agency, Alternative U.S. Policies for Reducing the Effects of a Cobalt Supply Disruption--Net Economic Benefits and Budgetary Costs, p. 31-34.

¹³Bureau of Mines, Cobalt - A Chapter from Mineral Facts and Problems, 1980 Edition, p. 6.

¹⁴Ibid.

¹⁵Federal Emergency Management Agency, Alternative U.S. Policies for Reducing the Effects of a Cobalt Supply Disruption--Net Economic Benefits and Budgetary Costs, p. 34.

¹⁶Bureau of Mines, Cobalt, Reprint from the 1981 Bureau of Mines Minerals Yearbook, p. 8.

¹⁷Ibid., p. 3-4.

¹⁸National Foreign Assessment Center, Strategic Materials - A Review of the Issues. NFAC GI 81-10162, Washington, D.C., November 1981, p. 18
SECRET/NOFORN (Information was only taken from unclassified paragraphs.)

¹⁹Bureau of Mines, Cobalt - A Chapter from Mineral Facts and Problems, 1980 Edition, p. 11.

²⁰U.S. General Accounting Office/Report to Secretary of the Interior, "Actions Needed to Promote a Stable Supply of Strategic and Critical Mineral and Materials."

²¹Bureau of Mines, Cobalt - A Chapter from Minerals Facts and Problems, 1980 Edition, p. 12.

²²Federal Emergency Management Agency, Office of Resources Preparedness, Alternative U.S. Policies for Reducing the Effects of a Cobalt Supply Disruption--Net Economic Benefits and Budgetary Costs (Washington: August 1982), p. 6.

²³Bureau of Mines, Cobalt - A Chapter from Mineral Facts and Problems, 1980 Edition, p. 12.

APPENDIX B -TITANIUM

B.1 An Introduction to Titanium.

The authors of this report all expressed a common interest in strategic and critical non-fuel materials during the first days of the Industrial College of the Armed Forces (ICAF) Mobilization Studies Program in August of 1982. This interest was borne from previous professional endeavors in various governmental agencies that dealt in a variety of ways with a multitude of these materials. Two of the authors were keenly interested in titanium, since both were exposed to the metal's attributes during development work on the B-1 bomber and F-15 fighter programs. This interest in critical materials, and specifically titanium, was stimulated further by an excellent lecture on strategic materials given to ICAF by Dr. John Morgan, Staff Director of the Bureau of Mines, in September of 1982.

Preliminary research of titanium revealed that approximately 70 percent of the titanium metal consumed in the U.S. was for aerospace applications. The applications included aircraft and guided missile assemblies, spacecraft, and turbine engines for aircraft. The remainder is used in chemical processing and in marine and ordnance applications. Titanium is a major material for both structural and rotating parts in the compressor section of turbine engines used in high performance military and civilian aircraft. Titanium alloys are used in turbine compressor blades, vanes, discs, engine cases, frames, struts and fairings. Titanium is used in airframe structures as a replacement for aluminum and steel to reduce the weight of selected parts.¹

U.S. production of titanium dioxide pigment in 1981 was about 750,000 tons, valued at about one billion dollars. Net shipments of titanium mill products were about 250,000 tons, worth about \$420 million. In 1981, these two major uses of titanium accounted for over 96% of domestic titanium consumption. The third largest application, the use of rutile for coating welding rods, required about 7,400 tons of rutile, worth about \$2.6 million. Other applications of titanium raw materials include the manufacture of titanium carbides, ceramics and chemicals, and the recently developed use of ilmenite as a substitute for barite in well drilling muds.¹

B.2.2 General Discussion.

Titanium ore reserves are abundant and widely distributed throughout the world. U.S. self-sufficiency in titanium ore has declined from 75% in the mid sixties to 40% in 1980. This decline occurred because U.S. reserves are limited with respect to its disproportionately large use of titanium products.

In recent years, the major change in the titanium ore situation has been due to large increases in the manufacture of rutile substitute from ilmenite, both domestic and abroad. Less visible, but of significant impact on the titanium ore supply in the future are: 1) the production of natural rutile has declined domestically, levelled off in Australia, and increased in South Africa; 2) the reserves of beach sands in Florida continue to shrink; 3) the new potential by-product sources of titanium have emerged. These include the recovery of accessory minerals from the Athabasca, Canada, tar sands, the recovery of titanium dioxide from chlorination of bauxite, and, the recovery of ilmenite from the tails of sand-day operation in California.²

B.2.3 Mineral Sources and Types of Ore Deposits.

The present mineral sources of titanium are ilmenite along with its alteration product leucoxene, and rutile. The foregoing paragraphs provide a brief description of the types of titanium ore deposits.

a. Ilmenite and Leucoxene.

The primary occurrence of ilmenite is in association with magnetite in hard rock deposits. Ilmenite and associated leucoxene also occur in fossil beach sands that are the erosional remnants of formerly massive hard rock deposits.

b. Rutile and Anatase.

Commercial occurrences of rutile and its slightly softer and lighter sister oxide anatase are mostly in beach sands deposits in which they are associated with ilmenite and leucoxene, and with other hard minerals. Rutile and anatase also are common components of complex igneous rocks, but rarely at a high enough grade for commercial recovery.

c. Perovskite and Sphene.

Neither mineral is produced commercially even though the occurrence of perovskite and sphene in igneous rocks is not uncommon. A commercial future for perovskite appears more likely than for sphene because perovskite is richer in titanium dioxide and has only calcium as its main impurity. Sphene contains as major components calcium and silica, which are both problem impurities.³

B.2.4 Worldwide Resources and Reserves.

The U.S. Bureau of Mines and the U.S. Geological Survey generally classifies "reserves" as deposits producible under current conditions with present technology. "Other resources" are those deposits containing titanium minerals in such form and grade as to be reasonably considered a source of titanium for the future.⁴ About 25 million tons of the U.S. resource is in a Colorado perovskite deposit for which suitable processing technology still has to be demonstrated. By-product sources of titanium concentrate, currently of small consequence, have the potential of making important contributions to production if suitable technology can be developed. Mining for conventional ilmenite and rutile deposits have changed little in recent years, except for techniques of making artificial rutile that are still being modified.

The U.S. ilmenite and perovskite resources are shown in table B.1. The ilmenite reserves in the U.S. (Table B.1) are estimated to contain 14 million tons of titanium. Rock deposits in New York account for 40% of the total. The remaining 60% is located in beach and river sands in Florida, Georgia, New Jersey, and Tennessee. An additional 47 million tons of titanium in ilmenite and 11 million tons in perovskite, not believed to be economically recoverable under present conditions, occurs in identified resources in several states. The major occurrences lie in Colorado, Minnesota, New Jersey, New York, Virginia and Wyoming.⁵

TABLE B.1 --U.S. Ilmenite and Perovskite Resources
(Thousands Short Tons of Contained Titanium)

	Reserves	Other	Total
California-----	---	3,500	3,500
Colorado-----	---	<u>1/</u> 10,600	10,600
Florida-----	5,600	1,400	7,000
Georgia-----	1,400	300	1,700
Idaho-----	---	1,100	1,100
Minnesota-----	---	6,600	6,600
New Jersey-----	600	6,000	6,600
New York-----	5,600	13,500	19,100
Oklahoma-----	---	2,200	2,200
Tennessee-----	800	1,800	2,600
Virginia-----	---	4,000	4,000
Wyoming-----	---	4,000	4,000
Other States <u>2/</u> -----	<u>---</u>	<u>3,000</u>	<u>3,000</u>
Total-----	14,000	58,000	72,000

1/ Colorado deposits are perovskite; all others are ilmenite or altered ilmenite.

2/ Includes Alabama, Mississippi, New Mexico, Oregon, South Carolina, and Washington.

TABLE B.2 --U.S. Rutile Resources
(Thousand Short Tons of Contained Titanium)

	Reserves	Other	Total
Arizona-----	---	2,700	2,700
Arkansas-----	---	200	200
California-----	---	200	200
Colorado-----	---	100	100
Florida-----	600	800	1,400
Georgia-----	300	100	400
Maryland-----	---	500	500
South Carolina-----	---	100	100
Tennessee-----	100	200	300
Utah-----	---	2,600	2,600
Virginia-----	---	900	900
Total 1/-----	1,000	8,400	9,400

1/ Colorado deposits are perovskite; all others are ilmenite or altered ilmenite.

U.S. reserves of rutile shown at table B.2, are in sand deposits in Florida, Georgia, and Tennessee. The reserves have a total titanium content of about one million tons. Identified, but presently subeconomic resources indicated at table B.2 occur mainly in Arizona, Florida, Utah and Virginia. These resources contain an estimated million tons of titanium in rutile. The resources of Arizona and Utah consist mainly of accessory rutile in porphyry copper ores and tailings which are being investigated by the Bureau of Mines and the Geological Survey as a potential sources of rutile.

Worldwide ilmenite, rutile and anatase resources are detailed in table B.3 and table B.4.⁶ World reserves of ilmenite are estimated to contain 214 million tons of titanium, of which U.S. reserves account for about 7%. The titanium content of world rutile and anatase reserves is estimated at 76 million tons, of which U.S. reserves represent 1.3%. Identified world resources of titanium total nesarly 600 million tons in ilmenite and 150 million tons in rutile and anatase.

TABLE B.3 --World Ilmenite Resources
(Million Short Tons of Contained Titanium)

	Reserves	Other	Total
India-----	50	80	130
Canada-----	49	37	86
Norway-----	40	5	45
South Africa, Republic of-----	33	117	150
Australia-----	18	9	27
United States-----	14	58 <u>1/</u>	72
U.S.S.R.-----	4	16	20
Finland-----	3	1	4
Sri Lanka-----	1	1	2
Brazil-----	1	2	3
Malaysia-----	---	1	1
New Zealand-----	---	7	7
Egypt-----	1	9	10
Mozambique-----	---	13	13
Other Countries-----	---	<u>17</u>	<u>17</u>
Total <u>1/</u> -----	214	373	587

1/ Includes 10,600,000 tons in perovskite in Colorado.

TABLE B.4 --World Rutile and Anatase Resources 1/
(Million Short Tons of Contained Titanium)

	Reserves	Other	Total
Brazil-----	55	28	83
India-----	5	12	17
Australia-----	6	1	7
South Africa, Republic-----	3	0.1	4
Sierra Leone-----	2	16	18
Italy-----	3	1	4
United States-----	1	8	9
U.S.S.R.-----	1	2	3
Sri Lanka-----	0.2	0.1	0.3
Other Countries-----	---	4	4
World Total 2/-----	76	73	149

1/ Brazilian resources are about 56% anatase. All other resources are rutile.

Outside of the U.S., reserves shown for Canada, Finland and Norway are in hard rock deposits ilmenite-magnetite. The remainder of the world's reserves is almost entirely in beach sands deposits. Most experts in the field agree that the necessity to improve technology has not been under pressure from economics and shortages of reserves, so there has been little

driving force for massive research into methods of recovering titanium from lower grade resources. Past and current efforts on such domestic resources have been mostly of a desultory nature as motivated by drifting views of the desirability for self-sufficiency in critical materials.⁷

B.2 TITANIUM -FOREIGN AND DOMESTIC RESERVES

END NOTES BIBLIOGRAPHY

¹Langtry E. Lynd, "Accessibility of Titanium Ores and Concentration," for presentation at a conference sponsored by the Colorado School of Mines, Sept 1982, p. 1

²National Academy of Sciences, National Materials Advisory Board Report No. NMAAB-381, Assessment of Selected Materials, (Washington, D.C. 1981), p. 65.

³Ibid., p. 76

⁴U.S. Dept. of Interior, Bureau of Mines, Minerals Commodities Summary, (Washington: U.S. Government Printing Office, 1982), p. 179.

⁵Lynd, "Accessibility of Titanium Ores and Concentration," p. 13.

⁶Ibid, p. 14.

⁷Ibid., p. 3.

B.3 Vulnerability.

B.3.1 General.

The majority of expert assessments of material vulnerability generally agree on which imported materials are most vulnerable to supply interruptions or to coercive price increases potentially damaging to the U.S. Regardless of the criteria used in classifying materials with respect to criticality, strategic importance, or vulnerability, certain minerals have repeatedly turned up on the most important or most vulnerable lists. Chromium, cobalt, manganese, and the platinum group metals are identified most frequently, with tantalum, titanium and columbian as the leading contenders in terms of vulnerability.¹

In terms of tonnages of contained metal, 92% of the titanium consumed in the U.S. is used for pigments in paints, paper and plastics and for other chemical products. However, titanium derives its strategic importance from the 8% of consumption used as metal. Approximately 60% of the titanium metal consumed in the U.S. goes into parts and assemblies for civilian and military aircraft, jet engines, guided missiles and spacecraft. The remainder is used in chemical and electrochemical industries, marine applications, military ordnance and other purposes. A more detailed explanation may be found in section B.1. of this report.

The major titanium bearing minerals are ilmenite and rutile. The former is more common and is the usual source for titanium for pigments. Rutile is more rare than ilmenite and is the major raw material for making

sponge metal. While the U.S. has concentrations of ilmenite in Florida, New York and New Jersey, its resources in rutile are mostly subeconomic. The nation depends upon imports of rutile and titanium sponge from Australian sources.² The report contains a detailed account of worldwide and domestic resources of titanium in section B.2 of this Appendix.

B.3.2 Market Factors.

Titanium is one of our newest engineering structural materials. Since the start of titanium production in 1950, there have been three characteristics that highlight an assessment of titanium availability.

First, the Industry has exhibited a repetitive pattern of overcapacity, interrupted by short periods when supply has been temporarily insufficient to satisfy customer delivery requirements. The industry is in such a cycle today. Since 1978, sponge and ingot capacity limitations throughout the world have been one cause of extended delivery commitments. There is strong evidence that the industry is now in a more normal period where supply will exceed demand and commercial considerations. Secondly, the commercial production of titanium metal in a competitive multi-source environment was established in the U.S. in 1950. Since then, the U.S. has been the world leader in the manufacture of titanium metal. It is in our national interest to maintain a strong titanium industry mainly because of its importance as a structural metal in military and commercial aircraft. Finally, unlike the case with many other strategic metals, dependence on foreign ore sources criticality is largely a function of the lead times postulated in a crisis scenario. The U.S. has sufficient ore, given the lead times and technology, to support anticipated critical titanium applications in the foreseeable future.³

Titanium is at a relatively early stage in its development when compared to other light metals such as aluminum and magnesium. There are remarkable similarities between the growth of the three metals, separated only by the time scale. Titanium's growth lags that of magnesium by 30 years and that of aluminum by 70 years. All three metals show the same fluctuation trends in production during the early years, followed by relatively more stable growth as commercial applications become a larger factor in the growth. Therefore, it seems reasonable to extrapolate the growth of titanium to the year 2000 on an exponential basis. A 6% growth rate projected from 1980 corresponds to a probable market in year 2000 to approximately 70,000 tons. The sponge requirement for 70,000 tons is about 150 million pounds of sponge, about twice the 1982-1984 U.S. capacity. However, prospects are excellent for large new applications to develop that will increase the capacity projection. Assuming an annual growth rate of 7%, with a doubling time of 10 years, U.S. production of 100,000 tons of mill products may be achieved by 2000.

It is probable that the sponge capacity of the world will lead demand by 15-25%. This has been the history of other metals and could be expected of titanium. With increased supply relative to demand, the price of titanium products should be reduced in the short term, perhaps as much as 25%. Then it would be followed by increased prices along with the general course of commodity price variation with inflation. In any case, the violent fluctuations experienced during the first 30 years of titanium's growth should dampen out considerably in the next 20 years.⁴

From 1970 to 1980, the price of rutile pigment increased from 45¢ to 98¢ a pound. The more strategically important sponge metal rose in price from \$1.32 to \$7.02 a pound in producer contracts. In 1982, the free market (dealer) price fell to about \$2.50 a pound. These price deviations are characteristic of titanium's up and down, cyclical market history.⁴

A major market problem for the industry is building capacity to meet demands that are intermittent and have deep low demand periods. The resulting idle capacity saps earnings and makes capital difficult to attract. The government, specifically the Department of Defense, would like the industry to possess the capacity to meet sudden surges in demand. These surges could result from new weapon system programs or by varying degrees of required national mobilization efforts.⁵ A historical perspective of the market profile of titanium is illustrated in figure B.1 of this section.

B.3.3 U.S. Import Reliance.

Rutile has been produced in the U.S. in limited quantities to date. Therefore, U.S. import reliance for rutile has generally been over 90% of consumption. Kerr-McGee's synthetic rutile plant production somewhat lowers the dependence on imported rutile but has a correspondingly increased reliance on imported ilmenite. U.S. imports of ilmenite and rutile in recent years have been predominantly from Australia, with imports of slag coming from Canada through 1978. In 1978, Sierra Leone, South Africa, and Sri Lanka began to export rutile to the U.S.; and considerable quantities of slag have been imported from the Republic of South Africa since 1979. U.S. import reliance for titanium in ilmenite plus slag ranged from 86,000 tons in 1975 to

214,000 tons in 1981, which ranged from 26% to 54% of consumption. Overall, import reliance for titanium in concentrates has ranged from 43% in 1970 to 65% in 1981. The historical relationship between consumption and import reliance for ilmenite and rutile is shown graphically in figure B.2.

The U.S. has large reserves of titanium in the form of ilmenite, and produces annually ilmenite concentrates which contain over 180,000 tons of titanium and several thousand tons of natural rutile concentrate. However, nearly all of the U.S. titanium sponge metal production has been driven from imported titanium concentrates. Therefore, it is important to state the reasons for this heavy reliance on foreign raw materials, and to examine the extent to which domestic concentrates could be used if a national emergency led to a cut-off of overseas imports. Titaniferous slag imports from Canada are assumed to continue to be available.

An analysis of available U.S. and Canadian raw materials supplies, without overseas imports, indicates that the total supply of titanium could equal approximately the 1981 domestic demand. This assumes that domestic mine production was at full capacity, and that producers would be augmented by large quantities of raw material stocks.

As late as 1976-1979, the U.S.S.R. supplied 21% of the titanium sponge used in the U.S.; but in 1979 and later, it greatly reduced its sales and began purchasing ore and metal in world markets. Since more than 65% of Soviet consumption of titanium is believed to be weaponry, this suggested that an arms buildup and stockpiling program was in progress. This occurrence leads one to believe that in the future the Soviet Union will be more of a

competitor than a supplier to the West for titanium. The Soviet Union is believed to be building deep-diving, high-speed submarines with hulls of titanium.

B.3.4 Hostile Action Impacts.

The Soviet Union, as a competitor for titanium and as an adversary of the United States, would most likely stop exports of titanium to the nations friendly with the U.S. in the event of war. Therefore, over one-fourth of all U.S. imports of titanium sponge that has been supplied by the U.S.S.R. would stop in wartime. Furthermore, according to the Federal Emergency Management Agency (FEMA), estimated annual U.S. wartime requirements could be more than three times the level of current U.S. capacity. If one assumes FEMA's forecasts are credible, the U.S. is vulnerable in the event of a war with the country or countries that are aligned with the Soviet Union. The same parallel could be drawn with a sea lane blockade that could cause an import supply cut-off. This vulnerability dependency could be postulated for the short term at least.

A review of U.S. dependency for titanium finds the U.S. is generally dependent on imports for 13% of total supply. During the years 1975-1978, a period of relatively high domestic demands for titanium, Japan provided 63% of the U.S. imports; the U.S.S.R. 27%; and the U.K. 10%. The U.S. imports in 1979 were 2500 short tons. This total would have been substantially higher, however, if the U.S.S.R. did not have a high titanium requirement for a new submarine and if the Japanese did not have a large requirement for desalinization equipment for the Middle East. According to

FEMA, import dependence will probably increase in the future since foreign expansion plans exceed domestic production expansion forecasts.⁶

Furthermore, continued high demand for titanium sponge may prevent significant acquisitions for the stockpile during the 1980s. This problem was identified in a study by the Federal Preparedness Agency entitled, "A Projection of U.S. Supply and Demand for Titanium Sponge to 1985." The study, published in February 1978, showed that even without the B-1 aircraft, stockpile purchases would result in an average shortfall of over 5,000 tons per year during the 1980s. Research has been initiated on follow-on B-1 weapons system that may require large quantities of titanium in the 1980s.

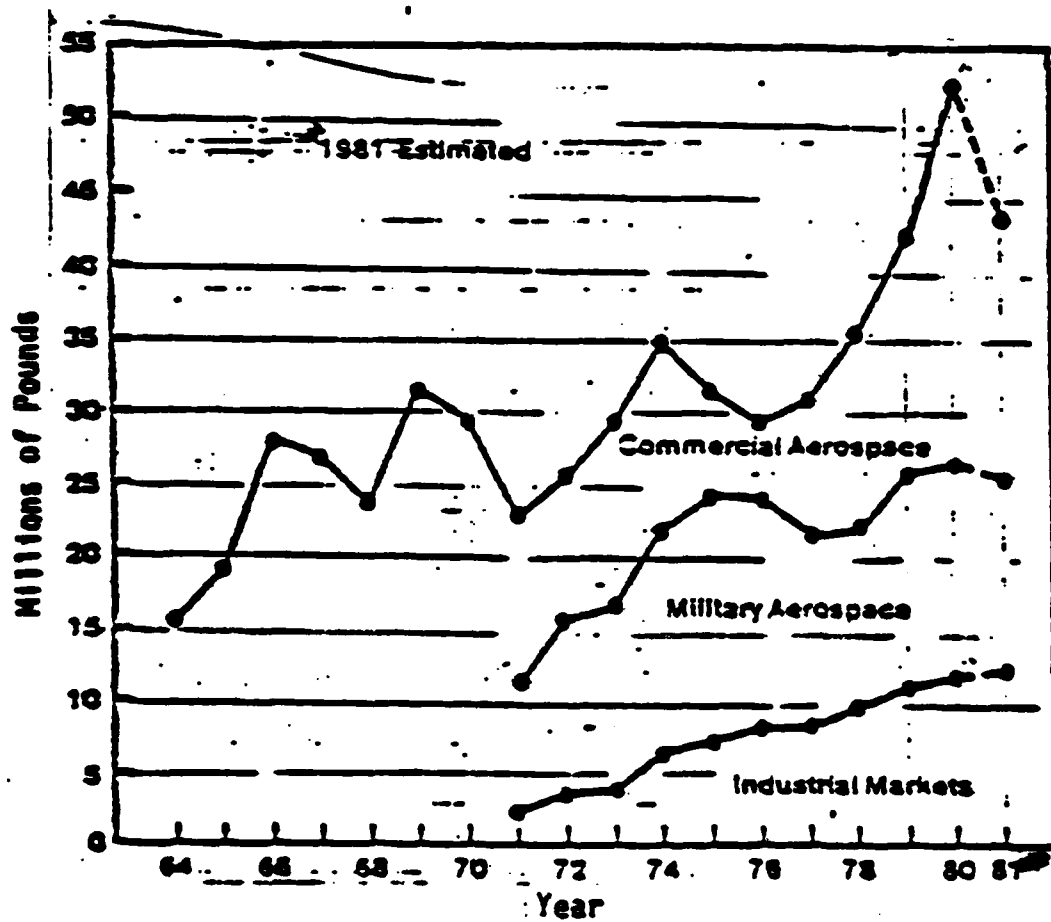
B.3.5 Summary.

The future requirement for titanium is extremely difficult to forecast. If we assume that titanium's development will parallel the other light metals, then we can extrapolate the growth of titanium to the year 2000 exponentially. A 6% growth rate corresponds to a probable market in year 2000 to 70,000 tons. This is about twice the 1982-1984 U.S. capacity. According to industry experts, prospects are good that new applications will increase the capacity projection. Some suggest that a U.S. production of 100,000 tons of mill products may be achieved prior to the end of this century. The question is then, how vulnerable are we to foreign pressures to include hostile actions?

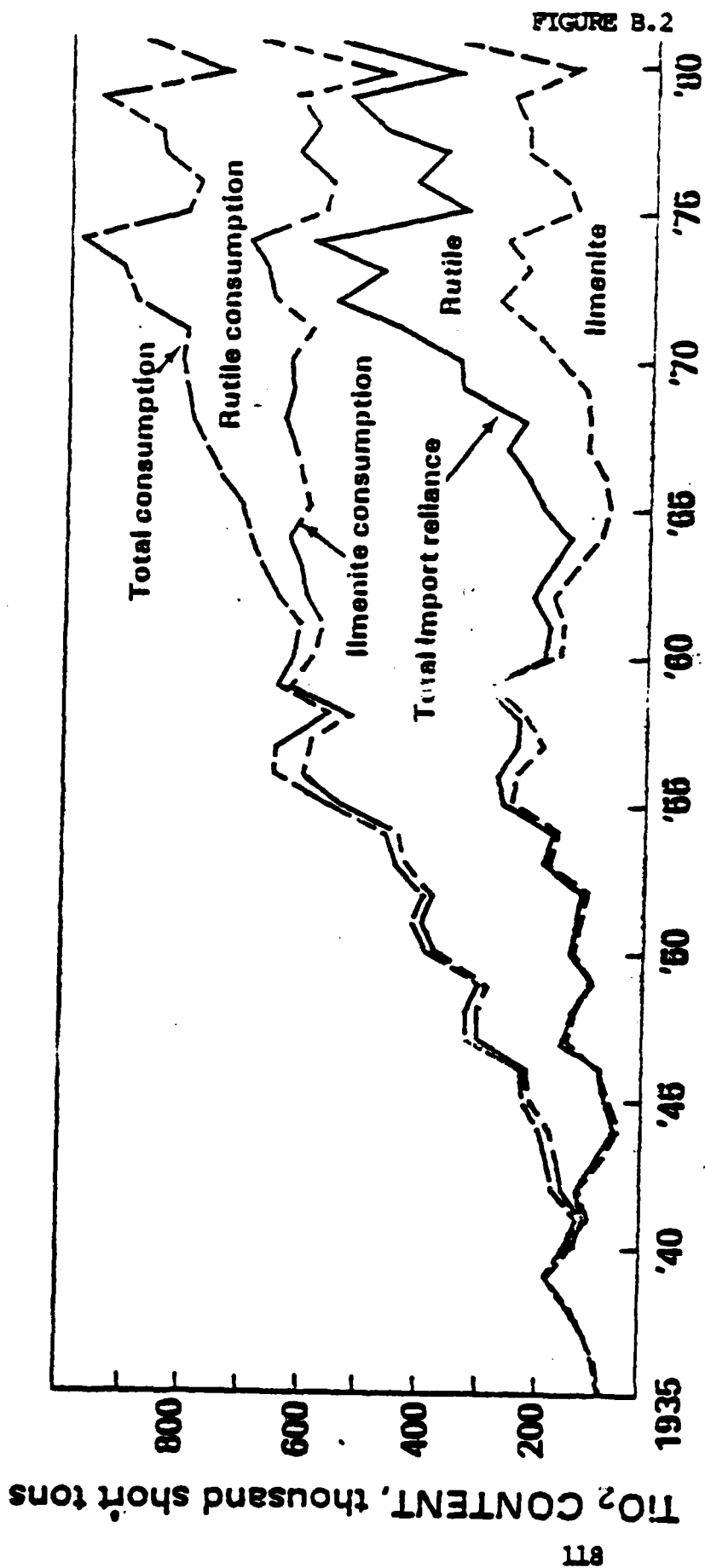
It would appear that the U.S. does possess adequate raw resources to meet projected demands within the continental U.S. The gap appears to be in adequate production and production technology to produce the quantities of

sponge metal to meet mobilization requirements. Given present stockpile and industry inventories, it appears the U.S. is vulnerable to foreign actions in a short term period of 6 months to 2 years. This time period is mainly based on the brick and mortar time to develop the foundaries and factories necessary to meet an increase of two to three times present demand. This assumes that the major U.S. producers could develop and apply the technology and production process necessary to meet demand while the construction (brick and mortar) was in process. The industry motivation to proceed vigorously in this area would have to come from a high confidence that there would be an attractive rate of return on capital expenditures. This confidence could be buttressed by government guaranteed stockpile expenditures, guaranteed pricing practices, or, a very real demand for defense applications because of war time requirement.

FIGURE B.1



TITANIUM INDUSTRY MARKET PROFILE



U.S. consumption and import reliance of ilmenite and rutile, 1935-1980

B.3 TITANIUM - VULNERABILITY

END NOTES BIBLIOGRAPHY

- ¹Alwyn H. King, "The Strategic Minerals Problem: Our Domestic Options," Parameters, September 1981, p. 44.
- ²James E. Sinclair and Robert Parker, The Strategic Metals War (New York: Arlington House, 1983), p. 125.
- ³Interviews with: Mr. Robert J. Mroczek, Commodity Industry Analyst, FEMA, Washinton, D.C., November 1982, Mr. Kenneth R. Foster, Staff Specialist for Materials Policy, Department of Defense, Washington, D.C., November 1982.
- ⁴Sinclair and Parker, The Strategic Metals War, p. 125.
- ⁵Interview, Mr. Kenneth R. Foster, Staff Specialist for Materials Policy, Department of Defense, Washington, D.C., Nov 1982.
- ⁶Interviews with: Mr. Robert J. Mroczek, Commodity Industry Analyst, FEMA, Washinton, D.C., November 1982, Mr. Kenneth R. Foster, Staff Specialist for Materials Policy, Department of Defense, Washington, D.C., November 1982.

B.4 Production and Substitutes.

B.4.1 Introduction.

Titanium metal is a low density, silver white metal with a high melting point (1670 C). The importance of titanium, as has been previously stated in this appendix, is due to a combination of lightness, strength and resistance to corrosion¹ (figure B.3). Titanium is the fourth most plentiful structural material in the earth's crust; and, is exceeded only by aluminum, iron, and magnesium. The two principal ores as stated in appendix B.2.1 are rutile (94% titanium dioxide) and ilmenite (63% titanium dioxide).

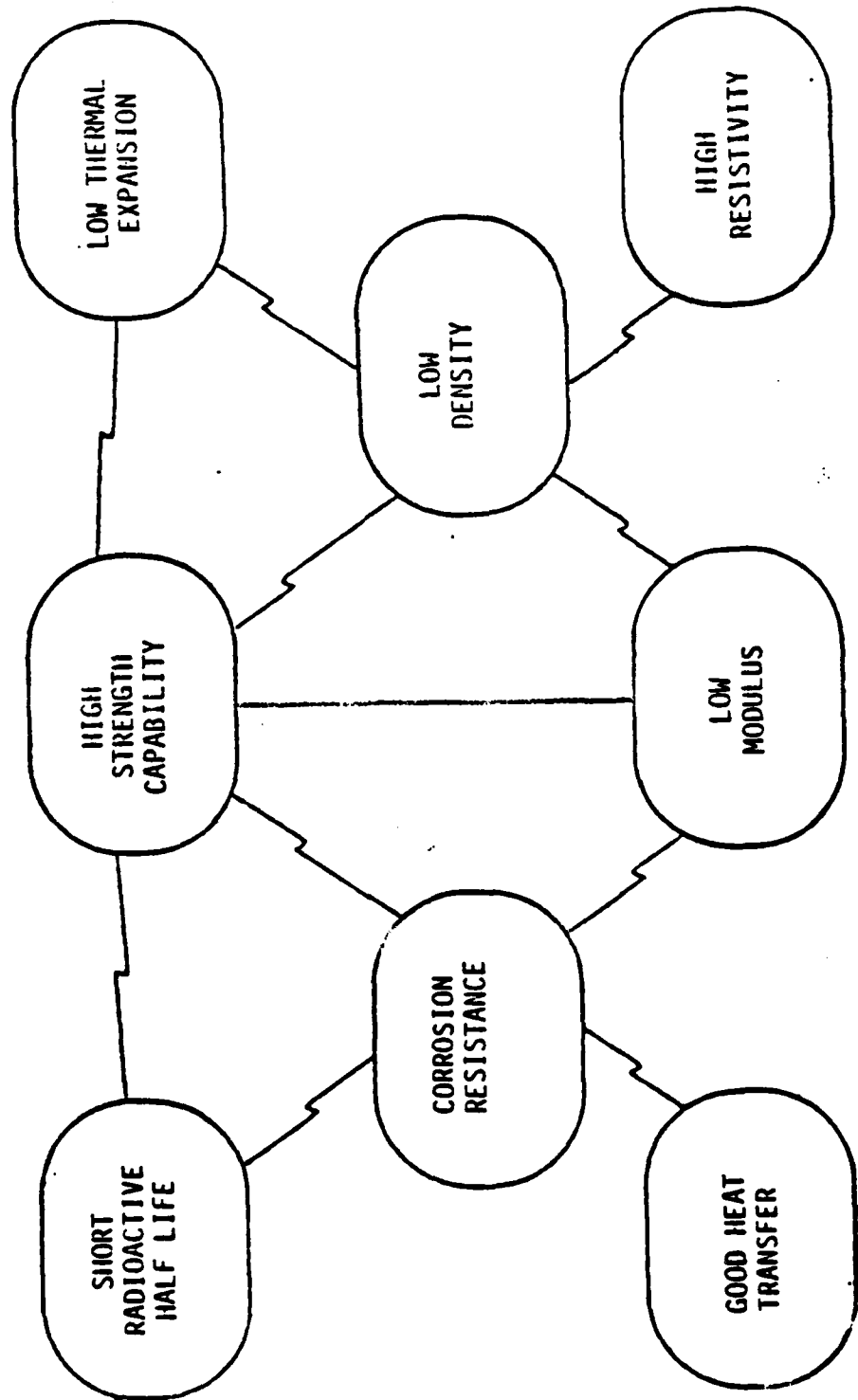
B.4.2 Production.

The production of titanium is essentially a chemical process. The titanium dioxide ore is combined with chlorine to produce a titanium tetrachloride liquid. The titanium tetrachloride is reacted with sodium in continuous reducers to form titanium dichloride and salt. This mixture is fed into argon-filled sinter pots which contain additional sodium. The sinter pot is heated, triggering a second reduction of titanium dichloride to titanium metal sponge and salt.

After several hours of heating the red hot sinter pot is removed from its furnace and sent to a cooling room. After cooling the pot is opened and the mixture of titanium sponge and salt is chipped out with pneumatic hammers and is fed into crushers where it is reduced to proper size for further processing.

FIGURE B.3

KEY PROPERTIES OF TITANIUM



The titanium sponge is then bleached, water washed, vacuum dried, and sampled for analysis. The sponge is combined with alloying materials in a 3000 ton press and assembled into electrodes for melting in a vacuum arc furnace. The consumable electrode is melted to form another consumable electrode for a second and then a third melt if specified. Thus a homogeneous ingot of titanium is created after cooling and the copper crucible is stripped away. The ingot is approximately 36" in diameter 12 feet long and weighs 20,000 pounds. These ingots are reduced by conventional metal working methods into mill products; billets, bars, sheet, and plate.²

The point of this somewhat tedious production methodology discussion is to illustrate that the creation of titanium is a complex one requiring a great amount of capitalization and a huge amount of highly reactive metal (sodium) and an equally great amount of energy. The yield of one pound of titanium mill product of this process is presented in figure B.4

B.4.3 History of the Industry.

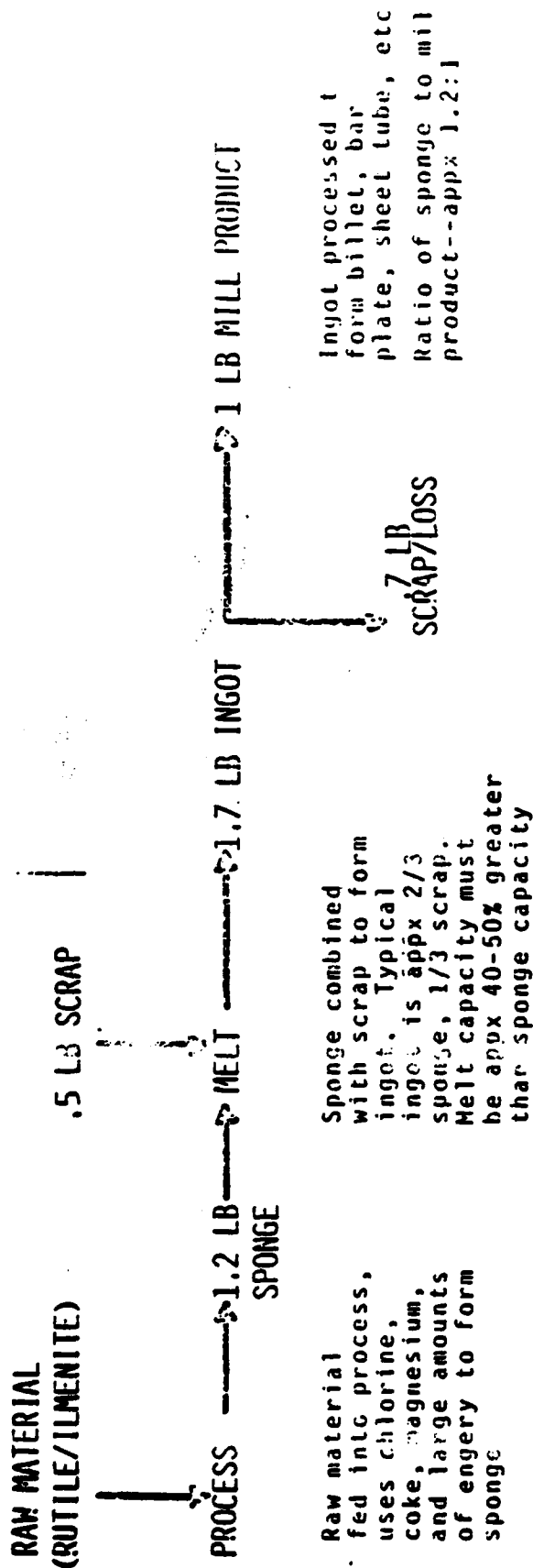
The titanium industry was born in the 1950's as a result of defense needs. Its birthright has also been its greatest detractor and source of industry turmoil. The production of titanium metal has thus been tied inexorably to the demand for aerospace applications. Seventy percent of the metal is used for these applications and as such has been tied to the feast or famine of defense budgets and technology changes.

Market demands has been extremely erratic (figure B.5). Because of large anticipated government and commercial aircraft contracts a number of companies entered the supply market. Many of the anticipated programs were terminated due to lack of political and economic support (e.g. the B-70, SST, and the B-1). Thus several companies withdrew from sponge production (Union Carbide, DuPont, Crane Company, Crucible Steel and Dow Chemical).³ In the 1960's, with increased defense spending, and a new generation of commercial aircraft, capacity was once again developed to meet demand. But, program terminations once again reduced demand substantially and most of the 1970's decade saw no change in this pattern.

Recent demand increases in the 1979 and 1980 timeframe for commercial aircraft and the restart of the B-1 program in 1981 created questions of industry capacity. At this same time the Soviets withdrew from supplying Western markets and other foreign suppliers began fulfilling internal markets. Now serious reservations were raised about titanium production capacity in the government. As quickly as demand increased it faded. Commercial aircraft orders dropped, the industry now had overbought and had large inventories on hand, government demand for defense applications stabilized and the overall down turn in the economy curtailed associated uses of titanium metal.

B.4.

FIGURE B.4. PRODUCTION PROCESS FOR ONE POUND OF TITANIUM MILL PRODUCT

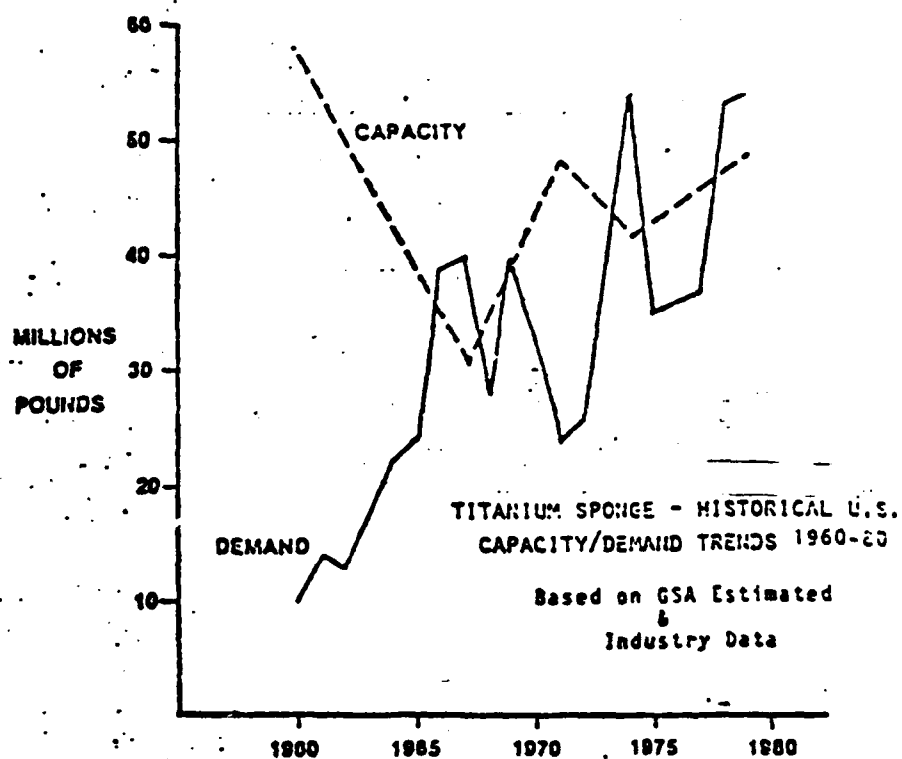


Raw material for production of titanium is plentiful. The conversion of the raw material to a usable form, however, is a costly, energy intensive process. The large capital investments required for production, coupled with the traditional uncertainty of the market, have inhibited capacity expansion.

To produce 1 million pounds of mill product requires about 1.2 million pounds of sponge capacity and about 1.7 million pounds of melt capacity.

NOTE: The figures cited above are approximations and vary from producer to producer and can also fluctuate annually depending on market conditions, scrap availability, etc.

FIGURE B.5



B.4.4 Present Output - Raw Material Supply.

The principal raw materials for the production of titanium metal are rutile and ilmenite. Less than 10% of these raw materials are converted into titanium metal. The remainder is treated to produce large quantities of pure dioxide used mainly for pigmentation in paints, varnishes, lacquers, paper, plastics, rubber, printing ink, and ceramics. Large quantities of titanium dioxide could be used for the production of metal instead of pigments if a national emergency should arise.

Rutile is a raw material containing 94% titanium dioxide and is found in Australia. Australia supplies nearly all of the imported rutile and the lower concentrate ilmenite or (63% titanium dioxide) to the U.S. The U.S. rutile and ilmenite reserves of 18.0 million short tons, about 18 years supply based on 1979 consumption suggest that availability of ore will not be a problem. However, during 1981 production of U.S. ilmenite was the lowest since 1950 as a result of reduced production by two Florida mines. In addition, Asarco shut down its mine near Lakehurst, New Jersey. This portends a problem for the future. Since the raw materials are imported, if those resources are cut off, it may take valuable time to reestablish domestic mining operations even in light of available reserves. Thus, the need for raw material stockpiles is imperative.

B.4.5 Present Output - Sponge supply.

Total U.S. sponge capacity was approximately 30,600 tons in 1981.

The major producers and their capacities are:

TIMET	15,000 Tons
RMI Co	9,000 Tons
Oregon Metallurgical Corp	4,500 Tons
Teledyne Wah Chang	1,500 Tons
D-H F. Titanium Co.	100 Tons

Nine U.S. companies produce titanium ingot and they are listed in Table B.5.

Sponge capacity expansion plans were being implemented in 1981.

International Titanium announced it would build a 5,000 ton per year plant at Moses Lake, Washington. Albany Titanium Co. announced a similar plant at Albany, Oregon of 250 tons expandable to 500 tons. TIMET is modernizing to increase capacity to 16,000 tons with potential to 20,000 tons. RMI was planning to go to 10,000 tons. Oregon Metallurgical Corp similarly, was increasing sponge capacity to 4,500 tons. However, in 1982 the economic downturn curtailed these expansion plans as demand dropped. Table B.6 provides the estimated U.S. and World capacities.

The problem of insufficient sponge and mill product capacity to satisfy demand surges in recent years was caused by inadequate capital investment in new plant and equipment. The industry has been plagued by volatile demand surges and capacity planning has been hampered by low priced sponge imports and slack demand.

TITANIUM

TABLE B.5 --Companies Producing Titanium Ingot in 1981

Company	Plant Location
Crucible, Inc., Colt Industries-----	Midland, Pa.
Howmet Corp, Alloy Div-----	Whitehall, Mich.
Lawrence Aviation Industries, Inc.-----	Port Jefferson, N.Y.
Martin Marietta Aluminum, Inc.-----	Torrance, Calif.
Oregon Metallurgical Corp-----	Albany, Oreg.
RMI Co.-----	Niles, Ohio
Teledyne Allvac-----	Monroe, N.C.
Teledyne Wah Chang Albany-----	Albany, Oreg.
Titanium Metals Corp. of America-----	Henderson, Nev.

TABLE B.6

Titanium Sponge
Estimated U.S. and World Capacities
(Million Pounds)

	<u>1981</u>	<u>1982</u>	<u>1983</u>	<u>1984</u>	<u>1985</u>
Timet	30.0	30.0	30.0	30.0	30.0
RMI	19.0	19.0	19.0	19.0	19.0
ORMET	9.0	9.0	9.0	9.0	9.0
D-H	0.5	1.0	2.0	5.0	10.0
TWCA	1.8	3.0	3.0	3.0	3.0
International Ti (1)	<u>-</u>	<u>5.6</u>	<u>5.6</u>	<u>10.0</u>	<u>10.0</u>
Total	60.3	67-68	68-69	76.0	81.0

Estimated World Capacities

United States	60.3	67-68	68-69	76.0	81.0
United Kingdom	6.0	7.0	7.0	7.0	7.0
Japan	60.1	66.0	66.0	66.0	66.0
China (PRC)	6.0	6.0	6.0	6.0	6.0
U.S.S.R.	<u>90.0</u>	<u>90.0</u>	<u>90-100</u>	<u>90-100</u>	<u>90-100</u>
Total	222.4	236-237	237-238	245-255	250-260

(1) Note: International Titanium, a new company (1981) has announced construction will begin in 1981 for an 1982 capacity of 7 million lbs. rising to 10 million lbs. beginning in 1983.

Source: Bureau of Industrial Economics.

B.4.6 Outlook for the Future.

The aircraft industry still accounts for 70% of the titanium metal use. Two other major markets include industrial equipment and steel alloying have been rather stable compared to the wide fluctuations in the aerospace industry. This demand uncertainty has fostered an extremely cautious approach to developing new processes and expanding capacity.

The demand for titanium for industrial equipment will continue to grow particularly in the chemical industry since the metal is highly corrosive resistant. Heat exchanges, water desalination equipment, and construction materials for underwater craft will provide increases in demand. Other future uses will include condensers, steam turbines blades, heat exchangers for nuclear power plants, automobile engine connecting rods and medical devices. Consumption by market is presented in Table B.7.

TABLE B.7

U.S. Titanium Metal Consumption by Market, 1968-79
(Thousand Short Tons of Titanium Content)

	<u>1968</u>	<u>1969</u>	<u>1970</u>	<u>1971</u>	<u>1972</u>	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>1977</u>	<u>1978</u>	<u>1979</u>	<u>1980</u>	<u>2000</u>
Aerospace	9	11	9	6	6	13	15	7	4	10	12	15	15	23
Industrial														
equipment	1	2	2	2	2	2	4	3	2	3	4	4	6	18
Steel and														
other alloys	<u>1</u>	<u>2</u>	<u>2</u>	<u>2</u>	<u>2</u>	<u>2</u>	<u>3</u>	<u>2</u>	<u>2</u>	<u>3</u>	<u>3</u>	<u>3</u>	<u>5</u>	<u>14</u>
Total	11	15	13	10	10	17	22	12	8	16	19	22	27	55

Source: U.S. Bureau of Mines.

B.4.7 Substitutes.

One method which has the effect of increasing titanium supplies is substituting another mineral. Another method which has the affect of increasing supplies is increasing the efficiency with which available supplies are consumed.

The major uses of titanium are keyed to its unique properties of light weight, high strength, high temperature, and corrosive resistance. The aerospace uses account for 70 percent of the titanium metal demand and no suitable substitutes are available which would not require severe performance penalties. Some alloy steel and aluminum can be used in aircraft structural application but the tradeoff once again is toward decreased performance. The demands in jet engine technology require titanium alloys in their manufacture and only titanium parts allow the engine to achieve its performance goals.⁵

There are other uses for titanium such as cutting tool bits (titanium carbide) and welding rod coatings where some substitution can take place. For example, tungsten carbide can replace titanium carbide and sodium can replace potassium silicates as welding rod coating. However, the overall quantities used here are small compared to the aerospace applications.

Similarly in pigment, the major use of titanium, titanium dioxide is of lower cost and provides higher opacity and brightness. Zinc oxide, talc, clay, silica, and aluminum can be substituted with performance degradation and increased cost.

However, some interesting programs are being accomplished to increase the efficiency with which existing supplies are used. These

programs have the same affect as increasing the productive capacity. There is a substantial trade-off between increased productive capacity and stockpile inventory level. Increasing efficiency by one ton is equal to three tons of stockpiled material similar to the relationship of increasing capacity.⁶

The research and development work is directed to minimize the impact of the possible strategic metals shortages and to minimize U.S. dependency. There are four broad areas of investigation:

- (1) Substitutes for items with critical and strategic mineral content,
- (2) Reclamation and recovery of critical minerals,
- (3) Life extension for components, and
- (4) Efficient processing.

Substitution includes all those cases in which high-critical content items are replaced with items of low or zero material content. Typical of this research are carbon/carbon and polyimide/graphite components replacing titanium for jet engine hot-section components. Composite materials research for replacement of titanium structural components is also being conducted.

Reclamation programs are considering the recovery of scrap and spent parts. Much material is lost through the manufacturing processes and the cutting chip scrap is expensive. Because of the tungsten and carbide content introduced during the machining process little use was made of these chips. Currently one manufacturer is processing the scrap, removing these

impurities, and is directing the overall purity to be acceptable for the most rigid specification applications in jet engine hot section parts. Life extension programs include research component life management i.e., developing the optimum replacement time and efficient repair cycles. Another area of investigation is the use of special castings for increased performance and conservation.

Efficient processing includes a wide range of programs which include:

(a) Powder metalurgy/hot isostatic pressing - this process involves placing tightly packed powdered metal containers conforming closely to the shape of the desired product. This container is subjected to high pressure (15,000 psi) and high temperature (1700-2000 F) in an autoclave. The result is a product which achieves 100% density of the metal all the mechanical properties and close to the net shape desired.

(b) Diffusion Bonding - pressure and heat are used to cause molecular bonding of two pieces of metal. This build-up process reduces material consumption and machining requirements.

(c) Superplastic forming - similar to diffusion bonding but is used for complex shapes and actually flows material under heat and pressure to net shape and thus reducing machining.

(d) Advanced casting technology - casting permits the initial amount of material required to be reduced and it can be used to form intricate shapes. Rheocasting and thixocasting are thick slurry processes which also produce extremely strong microstructures.

These are a few examples of research and development which rely on the build-up techniques rather than material removal techniques. Thus, conservation of material is achieved. In addition, these methods allow the opportunity to modify composition in order to impart special properties such as strength, toughness, corrosion resistance, and hardness.⁵

B.5 Mobilization Provisions.

B.5.1 The Stockpile.

The Strategic and Critical Materials Stockpiling Revision Act of 1979 sets forth the policy and intent of the Congress,

"...to provide for the acquisition and retention of stocks of certain strategic and critical materials and to encourage the conservation of sources of such materials within the United States and thereby to decrease and to preclude, when possible, a dangerous and costly dependence by the United States upon foreign sources for supplies of such materials in the times of national emergency."

The stockpile goals and inventory for titanium is in two forms:¹

(In stock pile sets)

<u>FORM</u>	<u>GOAL</u>	<u>INVENTORY</u>
Rutile	106,000 tons	39,186 tons
Titanium Sponge	195,000 tons	32,331 tons

Most of the acquisitions to the stockpile occurred more than twenty years ago and as such almost 11,000 tons of the sponge is not of stockpile grade.

In March 1981 the Administration directed the first addition to the stockpile in 20 years. However, only \$100 million was available in FY81 and \$120 million was requested in FY82. The overall stockpile goals are \$7 billion short and at those expenditure levels it will take 100 years to achieve the required inventory levels.²

The titanium industry has been plagued by volatile demand surges. The stockpile additions could provide a leveling influence if long term contracts for additions to the base were employed. In addition, a review and upgrade to the current inventory should be pursued. With any surge in defense requirements, the United States would not have enough titanium stockpiled to sustain the aerospace industry one year. The current and future aerospace systems production could be slowed severely, and this impact would predominately affect aircraft structural components and jet engine production.

B.5.2 Priorities and Incentives.

The Defense Production Act of 1950 provide two major avenues for attacking strategic and critical mineral problems. First, under Title I, it provides for a system of priorities and allocatins for materials to meet defense and energy needs. Under this system, the President is authorized to specify that orders relating to national defense be addressed on a priority basis and that materials be allocated to promote the national defense. The system of defense priorities and allocations is being simplified to promote understanding and easy use, and, to ensure the system could be expanded during a mobilization. Proposals have also been made to establish set-asides

under this system for certain critical minerals and materials such as cobalt and titanium. This would increase the availability of supplies for national defense programs and provide an equitable distribution among the suppliers.² The application of the priorities system with respect to titanium may not provide a great benefit however. Since a vast majority of the metal output already goes to defense needs, a priority system may only transfer material from one defense program to another with a possible increase cost to both.

Title III of the Act provides for incentives to expand capacity through loan guarantees, direct loans, and purchase of materials at guaranteed prices. The titanium industry incentives totalled \$900 million. The titanium industry was born as a result of Title III. A high proportion of the purchased materials found their way into the stockpile, although some do not now meet the stockpile specifications.

This concept of assistance to develop production capacity has been used successfully in the past and can be employed now to expand the titanium industry. Thus, it can fill defense production base gaps and reduce import dependence. In current stockpile planning, added domestic capacity reduces stockpile goals reflect three years of wartime consumption and take into account domestic production sources.

The major difficulty in both stockpiling and Defense Production Act incentives is the competition for extremely scarce dollar resources. The current economic situation, industry operating at 30-40 percent of capacity, and huge government deficits severely limit the implementation of crucial strategic and critical mineral policies.

B.5 TITANIUM - MIBILIZATION PROVISIONS
END NOTES BIBLIOGRAPHY

¹Federal Emergency Mangement Agency, Stockpile Report to the Congress,
October 1981 - March 1982 (Washington 1982), p. 20.

²Department of Commerce, Critical Materials Requirements of the U.S.
Aerospace Industry (Washington 1981) p. 224, p. 293.

Titanium Conclusions.

1. A historical analysis of the titanium industry has revealed that approximately 70 percent of the titanium metal consumed in the U.S. was for aerospace applications. Titanium is a major material used for both airframe structural and jet engine parts in high performance military and civilian aircraft. The latest aircraft could not have been built with the required performance specifications without titanium and titanium alloys. Future military and commercial aircraft are predicted to use titanium in approximately proportion of pounds per unit of production. In addition, the potential exists for a large number of industrial uses that could emerge to rival the aerospace industry. Therefore, the demand for titanium in the U.S. and world markets is expected to grow at a rate of 6 to 10 percent per year to the year 2000. This rate of growth does not include a full scale industrial mobilization to support a major war effort.

2. Titanium is the second most plentiful mineral in the earth's crust. There are vast resources available in the earth to supply worldwide projected requirements through at least the 21st century. Therefore, one can conclude that the recovery of ore is a matter of economy; and that the necessity to improve technology has not been under pressure from economies and shortages of reserves so there has been little driving force for massive research into recovering titanium from domestic grade resources.

3. The current policy of the Department of Defense is to rely on private investment for titanium capacity needed to satisfy defense requirements.

Titanium Recommendations.

1. Recommend the administration formulate a national policy to insure that sufficient quantities of titanium sponge are available to meet expected domestic and defense demands during a full scale war time mobilization effort. This policy should include: 1) a plan to divert non-essential domestic uses to defense needs; 2) the encouragement of DOD to use multi-year contracts; 3) government indentification for private capital investment in titanium facilities; 4) a program for additional federal funding for manufacturing technology projects to increase the commercial use of titanium.

2. Recommend the U.S. continue to import ilmenite and rutile from foreign sources as a matter of economy; however, a national policy is required to develop titanium production based on rich domestic ilmenite resources. Extensive technology does not seem to be required in that processes exist on the laboratory bench scale that must be carried through the pilot plant stage. A research and development government funding is required to bring on line a plant that would produce titanium tetrachloride. Titanium tetrachloride is the raw material for making sponge from domestic ilmenite.

The Department of Defense should improve procurement practices that would include, but not be limited to, the use of multi-year contracts. Further, the DOD should encourage the government to provide low interest on guaranteed loans, accelerated tax write offs and direct government funding to promote the use of domestic ores in national emergency.

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